TEXTBOOK OF VEGETABLE CROPS

PREM NATH
K.R.M. SWAMY

भाकृअनुप
ICAR
Indian Council of Agricultural Research
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Preface

IN recent years, the growing importance of vegetables has been recognized worldwide because of their vital role in food and nutrition security, and their emerging awareness on combating non-communicable diseases and health improvement. The production, consumption and movement of fresh and processed vegetables have increased considerably because of improved technology, consciousness in diet and improved transportation within and across the countries.

In addition, vegetable crops have become an important source of employment and income generation both is rural and urban areas with peri-urban horticulture assuming its role. In this edition, attempts have been made to update the readers on all aspects of vegetable crops and their production as much as possible.

New chapters, namely, The food value of vegetables; Vegetable nutrition and human health; Food security and vegetables; Plant growth and development; Modes of reproduction in vegetable crops; Types of vegetable farming; Plant nutrition; Establishment of vegetable crops in the field; Principles of vegetable production; and Principles of vegetable seed production are important for the changing scenario.

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Prem Nath
K.R.M. Swamy

Contents

CHAPTER 1

Introduction

THE term vegetable in its broadest sense refers to any kind of plant life or plant product; in the narrower sense, it refers to the fresh, edible portion of a herbaceous plant consumed in either raw or cooked form. The edible portion may be a root, such as rutabaga, beet, carrot, and sweet potato; a tuber or storage stem, such as potato and *taro*; the stem, as in asparagus and kohl *rabi*; a bud, such as brussels sprouts; a bulb, such as onion and garlic; a petiole or leafstalk, such as celery and rhubarb; a leaf, such as cabbage, lettuce, parsley, spinach and chive; an immature flower, such as cauliflower, broccoli, and artichoke; a seed, such as pea and lima bean; the immature fruit, such as eggplant, cucumber and sweet corn (maize); and the mature fruit, such as tomato and pepper (Warid 2011). The popular distinction between vegetable and fruit is difficult to uphold. In general, those plants or plant parts that are usually consumed with the main course of a meal are popularly regarded as vegetables, while those mainly used as desserts are considered fruits. Thus, cucumber and tomato, botanically fruits, are commonly regarded as vegetables.

Origin of vegetable crops

The vegetable kingdom is dominated by about 110 botanical families, consisting of about 1,000 species under commercial cultivation as major and minor crops distributed across the globe. These crops are distributed all over the world but adapted to different climatic regions like temperate, sub-tropical and tropical regions of the world (Nath *et al.* 1987). But some crops like tomato, onion, potato, watermelon, pumpkin and others are grown all over the world. India is a home for about 100 vegetable crops produced commercially as major or minor crops. (Swarup 2006) reported that India is the secondary centre of diversity for many introduced vegetables. The genetic diversity among the known species clearly indicates the differences in their evolution, domestication and improvement. Some of the species probably have originated from the tropics, while the others may have been introduced and became well adapted to tropical conditions. The process of domestication of cultivated crops started about 10,000 years ago or less (Grubben 1977) gave 5 phases of domestication of vegetable crops and suggested that approximately 1,500 wild species were likely to be involved originally in the process. Man selected only those wild vegetable plants that were useful to him principally for food, and traveled with them. The natural distribution pattern of

cultivated tropical vegetable species has been greatly upset by man's activities in transporting them from continent to continent. The pattern of distribution of plant species within countries is influenced by agro-climatic conditions, farming practices, local preferences and other factors (Nath *et al.* 1987).

Each of the world's basic vegetable crops originated in a relatively confined geographic region. The regions overlap for a number of crops. But 9 major and 3 minor centres in the old world (Africa, Asia and Europe) and new world (America) respectively, have been identified as the areas for the origin and delivery of the vast majority of vegetables. The criteria for assigning a particular geographic region to a specific vegetable are the availability of considerable variability, presence of wild forms and existence of source of resistance to many of the diseases. Historical records, fossil records and archaeological findings add to this information.

Knowledge regarding gene centers of cultivated plants and their possible wild ancestors (progenitors) serve as guidelines to collect main sources of genetic resistance to parasitic and non-parasitic diseases, insect-pests and nematodes. In these centers of origin, the vegetable crops have long been exposed to the selective pressure of local pathogens and insect-pests, and have developed inherent basic resistance. The role of gene centers of plants as sources of disease and pest resistance can not be ignored. Systematic exploration of primary and secondary gene centers of particular vegetable may provide additional gene pools for resistance breeding. Exploration and exploitation of gene centers, therefore, must proceed with the systematic co-operation of taxonomists, geneticists and plant pathologists.

The centres of origin of a few of the vegetables are as under (Peter, 1998):

Ethiopia: Bottle-gourd (2n=22, 44), celery (2n=22), cucumber (2n=14, 28), cowpea (2n=22, 24), fenugreek (2n=16), garden pea (2n=14), okra (2n=130), onion (2n=16, 32), watermelon (2n=22), and west Indian gherkin (2n=24).

Mediterranean: Asparagus (2n=20), cabbage (2n=18), beets (2n=18,19, 20, 27), cauliflower (2n=18), celery (2n=22), garlic (2n=16-secondary), great headed garlic (2n=16), kale (2n=38), knolkohl (2n=18), leek (2n=32), lettuce (2n=18, 36+B), onion (2n=18, 36), and turnip (2n=20).

Asia Minor: Beans (2n=22-secondary), beets (2n=18, 19, 20, 27), sprouting broccoli (2n=18), cabbage (2n=18), carrot (2n=18), chive (2n=16, 24, 32), kale (2n=38), lettuce (2n=18, 36+B), mustard (2n=36), onion (2n=16, 32), pea (2n=14), and brussels sprouts (2n=18).

Central Asiatic (Afghanistan, Turkestan): Bottle-gourd (2n=22, 44), broad bean (2n=12, 14, 24), carrot (2n=18), garlic (2n=16), mustard (2n=36), onion (2n=16, 32), pea (2n=14), spinach (2n=12, 24), and turnip (2n=20).

Indo- Burma: Amaranthus (2n=32, 34), ash-gourd (2n=24), Ceylon spinach (basella) (2n=44, 60), bread fruit (2n=54, 56), brinjal (2n=24), bitter-gourd (2n=22), chekkurmanis (2n=not known), cluster bean (2n=14), coleus (2n=32), colocasia (2n=28, 36, 48), cowpea (2n=22), cucumber (2n=14, 28), curry leaf (2n=18), dolichos bean (2n=22,24, 44), drumstick (2n=22), elephant foot yam (2n=24, 48), musk melon (2n=24, 48-secondary), pointed-gourd (2n=22), ridge-gourd (2n=26), snake-gourd (2n=22), snap melon (2n=24, 48), spinach beet

(2n=18, 24), and winged bean (2n=18), and yam (2n=40).

Siam, Malaya, Java: Ash-gourd (2n=24), breadfruit (2n=54, 56), colocasia (2n=28), curry leaf (2n=18), elephant foot yam (2n=26, 28), ginger (2n=22), and yam (2n=40).

China: Adzuki bean (2n=22), coleus (2n=32), cowpea (2n=22, 24-secondary), French bean (2n=22-secondary), leaf mustard (2n=36), musk melon (2n=24, 48), radish (2n=18), soybean (2n+40, 80), and turnip (2n=20).

Mexico-Guatemala: Amaranths (2n=32, 34), chilli (2n=24), chow chow (2n=24), French bean (2n=22), jack bean (2n=22, 44), Lima bean (2n=22), runner bean (2n=22, 24), squash (2n=24, 40), sweet potato (2n=90), and tomato (2n=24).

Peru, Ecuador, Bolivia: Chilli (2n=24), corn (2n=20), French bean (2n=22), Lima bean (2n=22), potato (2n=48), pumpkin (2n=24), runner bean (2n=22,24), squash (2n=24, 40), tapery bean (2n=22), tomato (2n=24), and xanthosoma (2n=12, 13).

Southern Chile: Potato (2n=48).

Brazil, Paraguay: Tapioca (2n=36).

United States of America: Globe artichoke (2n=34), and Jerusalem artichoke (2n=102).

Importance of vegetables

Increased production and consumption of horticultural crops particularly vegetables with its wide adoption and provider of important nutrients offers promise for the future. Vegetables are rich sources of nutrients (especially vitamins and minerals), besides their medicinal values. As such vegetables as food and diet supplement are gaining momentum in most countries in the recent years. Vegetables are higher in productivity than other crops. They provide more food per unit time and area of land. Hybrid cabbage and chinese cabbage, yield upto 40–60 tonne/ ha in 3 months. The more recent advances in technology, particularly hybrids and biotechnology, have added value to this group of crops in terms of efficiency and quality (Nath *et al.*, 2002). Since 1995 the FAO's Special Programme on 'Food Security' has amply demonstrated in the field the role of vegetable crops among poor communities, in the Low Income Deficit Countries world-wide (Kobakiwal, 2002).

The International Conference on vegetables with the theme, 'Vegetables for Sustainable Food and Nutrition Security in the New Millennium', concluded that 'Vegetables', as the important and major supplement to the food and nutrition security (Nath and Dutta 2004). According to International Food Policy Research Institute (IFPRI, 1999), about 52% of the developing world's population will be living in urban areas by 2020, up from 38% in 1995 leading to tremendous growth of mega cities. The rapid urbanization of the developing world and associated changes in life-style will have significant bearing on food preferences and food demand. Here, the periurban agriculture will play important role and vegetables will dominate because of their unparallel advantage of cultivation and production coupled with their nutritive values. Further, in 2020 one out of every four children in the developing countries will be malnourished (IFPRI, 1999) and here, the role of vegetables in the diet cannot

be ignored. As for example, the underlying significance and importance of 1 kg mung bean seeds producing 9 kg highly nutritious sprouts needs higher consideration by the producers and consumers in the upcoming scenario. FAO/WHO (2004) have recommended that the adequate consumption of fruits and vegetables (400 g/caput/day) improves health and prevents non-communicable diseases including cancer and obesity.

Table 1: Area, production and productivity of vegetable crops in India (1991–92, 2001–02 to 2013–14)

Year	Area (000 ha)	Production (000 tonne)	Productivity (tonne/ha)
1991–92	5,593	58,532	10.5
2001–02	6,156	88,622	14.4
2002–03	6,092	84,815	13.9
2003–04	6,082	88,334	14.5
2004–05	6,744	1,01,246	15.0
2005–06	7,213	1,11,399	15.4
2006–07	7,581	1,14,993	15.2
2007–08	7,848	1,28,449	16.4
2008–09	7,981	1,29,077	16.2
2009–10	7,985	1,33,738	16.7
2010–11	8,495	1,46,554	17.3
2011–12	8,989	1,56,325	17.4
2012–13	9,205	1,62,187	17.6
2013–14	9,396	1,62,897	17.4

ha, hectare, t, tonne; (Source: NHB, 2013–2014)

Production scenario of vegetables

Horticultural sector is the largest sub-sector of agriculture in India. This sector accounts for over 8.5% of the Gross Cropped Area (GCA) as against a level of 0.58% of the GCA during 1952–53 and 2.3% during 1984–

Table 2: State-wise area, production and productivity of vegetable crops in India during 2013–14

States/ Union Territories	Area ('000 ha)	Production ('000 tonne)	Productivity (tonne/ha)
States			
West Bengal	1,380.3	23,045.0	16.7
Uttar Pradesh	859.4	18,545.0	21.6
Bihar	809.8	15,097.8	18.6
Andhra Pradesh	439.6	8,149.8	18.5
Telangana	220.9	3,647.3	16.5
Gujarat	582.3	11,571.2	19.9
Karnataka	418.7	7,500.7	17.9
Tamil Nadu	289.7	8,678.8	30.0
Odisha	677.3	9,433.7	13.9
Maharashtra	726.0	10,161.8	14.0
Haryana	373.2	5,565.9	14.9
Chhattisgarh	403.4	5,465.9	13.5
Jharkhand	313.6	4,238.1	13.5
Madhya Pradesh	628.7	13,019.3	20.7
Punjab	191.0	3,936.2	20.6
Kerala	147.7	3,572.7	24.2
Asom	281.4	3,031.9	10.8
Jammu & Kashmir	63.1	1,395.5	22.1
Himachal Pradesh	86.6	1,635.9	18.9
Uttarakhand	88.3	1,016.8	11.5
Rajasthan	148.9	1,114.1	7.5
Tripura	46.7	780.5	16.7

(Contd...)

(*Table 2: Continued from p. 4*)

States/ Union Territories	Area ('000 ha)	Production ('000 tonne)	Productivity (tonne/ha)
Delhi	27.3	437.0	16.0
Meghalaya	43.6	515.3	11.8
Manipur	25.2	271.0	10.8
Sikkim	26.1	134.5	5.2
Mizoram	41.1	254.1	6.2
Nagaland	38.6	492.4	12.8
Goa	7.0	79.9	11.4
Union Territories			
Arunachal Pradesh	1.4	35.0	25.0
Andaman & Nicobar	6.9	51.8	7.5
Lakshadweep	0.3	0.3	1.3
Puducherry	0.9	16.3	18.1
Dadar and Nagar Haveli	1.1	5.5	5.0
Chandigarh	0.0	0.0	0.0
Daman and Diu	0.0	0.0	0.0
Total	9,396.0	162,896.9	17.3

ha= hectare; t= tonne; (*Source:* All India 2013–14, Department of Agricultural and Co-operation).

85. The area under vegetable crops has increased from 5.59 million ha in 1991–92 to 9.396 million ha in 2013–14 and its production increased from 58.53 million tonne in 1991–92 to 162,897 million tonne in 2013–14 (Table 1). India is the second largest producer of vegetables (next only to China) in the world.

Estimates showed that the share of fruits and vegetables in gross calorific value of food items produced increased from 3.1% in 1950–51 to 4.8% in 1993–94 and further to more than 6.0% at the beginning of the millennium. On account of the emerging demand for diversification, there has been perceptible increase in the outlay for horticultural development programmes, which increased from ₹789 crore in VIII Five-Year Plan to above ₹ 3,200 crore in X Five-Year Plan. At the farmer's level, horticultural crops offer greater promise for uplifting the small-and-marginal farmers by providing quick and regular income through their high productivity. A comparison of compound growth rate indicated 4.3 and 3.7% for fruits and vegetables when compared with 2.4 and 2.6% for foodgrain between 1972–85 and 1985–95 (Singh *et al.*, 2004).

Table 3: Area and production of different vegetable crops in India during 2013–14

Vegetable crops	Area ('000 ha)	Production ('000 tonne)	Productivity (tonne/ha)
Brinjal	711.3	13,557.8	19.1
Cabbage	400.1	9,039.2	22.6
Cauliflower	433.9	8,573.3	19.8
Okra	532.7	6,346.4	11.9
Onion	1,203.6	19,401.7	16.1
Peas	433.6	3,868.6	8.9
Tomato	882.0	18,736.9	21.2
Potato	1,973.2	41,555.4	21.1
Sweet potato	105.9	1,087.9	10.3
Tapioca	228.3	8,139.4	35.7
Other	2,491.6	32,591.3	13.1

ha= hectare; t= tonne; (Source: Indian Horticulture Database 2014, National Horticulture Board)

Although vegetables are widely distributed all over India, the lead producing states are West Bengal

(23.0450 million tonne), Uttar Pradesh (18.545 million tonne), Bihar (15.098 million tonne), Madhya Pradesh (13.0193 million tonne), Gujarat (11.5712 million tonne), Maharashtra (10.1615 million tonne), Odisha (9.4337 million tonne), Tamil Nadu (8.6789 million tonne), Andhra Pradesh (8.1498 million tonne), Karnataka (7.5007 million tonne) etc Table 2. The data on area, production and productivity of different vegetable crops in India during 2013–14 are also furnished in Table 3.

The present scenario of transition from the traditional subsistence farming by small farmers to commercial farming by large farmers and corporates is increasingly becoming important to make farmers ready for such changes. In the upcoming scenario of supermarkets and rapid growth of supply chain pre-dominated by skill of trade and value-addition, all efforts will be required to develop strategies which are knowledge based, technology driven, farmer centered and fulfil the consumer's demand of quality and supply. ●

CHAPTER 2

The Food Value of Vegetables

RECENTLY vegetables had received less attention by scientists and policy-makers than other crops (e.g., cereals, fruits and industrial crops) mainly due to attention focused on food quantity and economic returns. The recent reports indicate that malnutrition is affecting a large population, because of food scarcity causing malnutrition in large population or excess consumption in some causing obesity. Vegetables are important to human diet because of their precious nutrition components like vitamins, minerals, antioxidants and series of micronutrients, indispensable for human health (Bozzini, 2002). The vegetable production in India was less than 20 million tonne during 1947 when India became independent. Production of vegetables till 1961–62 was about 23.45 million tonne, which increased to 28.36 million tonne in 1967–71 and to 39.99 million tonne in 1986. According to latest statistics vegetables are grown on 8.989 million ha with the production of 156.325 million tonne with an average productivity of 17.4 tonne/ha (NHB, 2011). Globally, India ranks second in vegetable production and contributes 15.7% to global vegetable area and 14.5% to production. Compared to area (2.84 million ha), production (16.5 million tonne) and productivity (5.8 tonne/ha) in 1950–1951, there had been phenomenal increase in area (2.99-fold), production (8.88-fold) and productivity (2.96-fold) of vegetables in our country during the last 6 decades (IIVR. 2012).

In the next 10 years, it is estimated that there will be increasing trend for vegetable crops as vegetable farming is proving more remunerative than other crops. Of late, the interest in vegetable production has increased rapidly as a result of greater appreciation of the food value of vegetables and of the place of vegetables in the nation's food economy. The findings of scientific study and their wide application in the field have enhanced this interest to a great extent among growers and consumers alike. Vegetables belong to about 13 plant families and have originated from widely differing parts of the earth. Some of them are said to be native of India.

Vegetables are so common in human diet that a meal without a vegetable is supposed to be incomplete in any part of the world. An improved diet is supposed to have about 400 g of vegetables/day/caput, but in India the average per caput consumption of vegetables/day is reported to be significantly less. Vegetables contain proteins, carbohydrates, minerals, vitamins and roughages which constitute the essentials of a balanced diet. Surveys carried out in different parts of the

country have shown that the chief deficiencies in our diet are calories, retinol (vitamin A and riboflavin B_2). It has been pointed out that the protein yield per acre (0.4 ha) of the leafy green vegetables far exceeds that from other sources and they can also supplement the amino acid consumption through cereals and pulses. Leafy and some other vegetables can supply calcium and iron at low cost. Vegetables like tomato, muskmelon, bittergourd and *tinda* (round gourd) are rich sources of vitamin C, which also facilitate the absorption of these minerals. Also, vegetables like carrot, spinach beet, spinach, amaranth, musk melon, water- melon are rich in vitamin A. So far as the availability of riboflavin is concerned, next to animal sources, green leafy vegetables are the best sources. It is needless to say that peas and beans are the best sources of proteins. It has not been realized yet that a liberal consumption of vegetables can reduce the need for cereals which contain more of carbohydrates.

Vegetables in human diet

Vegetables play an important role in human diet, essential for a balanced diet and maintenance of good health. They are necessary in neutralizing the acids produced during digestion of meat, cheese and other fatty foods. They are valuable roughages (fibre) which promote digestion and help easy bowl movement in the digestive system. They supply carbohydrates, fats, proteins, vitamins and mineral elements, which are vital requirements for the body. Though vitamins occur in small quantities in vegetables, they produce profound and specific physiological effects. If properly and regularly used, vegetables can give a clear soft skin and bright eyes better than any cosmetics.

Vegetables as sources of minerals

About 10 mineral elements are needed for proper growth and development of the human body. Out of these, calcium, iron and phosphorus are required in large quantities, which are not present in sufficient quantities in other food articles except in vegetables. Besides, substances like iodine and sodium are also supplied by vegetables. Although they are present in minute quantities in vegetables, they are of considerable importance to human health. On account of the presence of minerals, vegetables are also protective foods (like milk), and thus, are very important in case of those who prefer a vegetarian diet. The following minerals are found in vegetable crops:

Calcium: It is badly lacking in many Indian diets and is needed for healthy bones and for resistance to infections. Children suffer from rickets, pigeon chest, irritability and retarded growth because of less intake of calcium. Their teeth become weak, and lack of calcium in the diet may cause difficulties at child-birth. It also acts as a co-ordinator among the mineral elements and helps regulate proportion of other elements. Presence of calcium in abundance aids in the economy of iron intake in the body. Beans, cabbage, carrot, cauliflower, lettuce, onions, spinach, peas, tomatoes and green vegetables provide good amount of calcium to the human system. Therefore, to supply enough calcium to the body, above vegetables need to be included in the daily diet.

Iron: It is richer in vegetables than in fruit crops. Most of the iron requirements

of the body can be had from green leaves and even nutritional anaemia can be easily cured by the leafy vegetables. Iron is the integral essential part of the red blood corpuscles (RBC) and is the best known oxygen carrier in the body. It can also be obtained from spinach, lettuce, cabbage, peas, beans and tomatoes.

Phosphorus: It is essential for all active tissues of the human body. Phosphorus is required for cell multiplication of both bones and soft tissues. It plays an important role in the oxidation of carbohydrates which liberate energy. It can be had in enough quantities from vegetables like potatoes, carrot, tomato, cucumber, spinach, cauliflower and lettuce.

Vegetables as sources of vitamins and amino acids

The important vitamins found in the vegetables are as under:

Vitamin A: It is also known as Retinol which is fat-soluble and essential for growth and reproduction in human beings. Its deficiency in the diet causes: night-blindness and sore eyes; increased susceptibility to infections of respiratory and digestive tract; formation of the stones in kidney and bladder; dryness, pimples, roughness and eruptions of skin and rough skin in children and; retarded growth of children who are constantly susceptible to diseases. Proper supply of vitamin A in human body keeps eyes bright, growth normal, intestinal tracts and respiratory organs in a healthy condition. It can be obtained from carrot, peas, turnip, beets, tomato, sweet potato and green vegetables like spinach, *methi*, green onion, green chilli, cabbage and lettuce. When leafy vegetables are consumed, contain carotene, which is converted into vitamin A in the body. It can be used then immediately, if required or stored in liver for future use. On an average, 120 g greens contain 2,000 to 12,000 international units (IU) of vitamin A which are sufficient to meet the daily needs of an adult human.

Vitamin B_1: It is known as Thiamin, and its deficiency may cause *Beri beri*, loss of appetite, loss of weight, and fall in the body temperature. It is essential for growth and reproduction. Green leaves are rich in vitamin B_1. Vegetables like lettuce, cabbage, green chili, carrot and onion contain vitamin B_1 which is not evenly distributed in all vegetables. In leguminous vegetables like peas, beans etc, it is found more concentrated in seeds than in leaves.

Vitamin C: It is also known as Ascorbic acid and it or, is water soluble. It is essential for general good health. Its deficiency in the body may cause unhealthy gums, tooth decay and rheumatism, 'scurvy' disease in children and adults, loss of energy, delay in wound healing and increased susceptibility to diseases, enlargement of heart and damage to heart muscles. Green vegetables like *methi*, spinach, lettuce, cabbage, green chilli and other boiled vegetables are good sources of vitamin C than fried ones because, cooking destroys a part of vitamin C. Tomato which can be consumed daily in adequate quantities provides sufficient vitamin C to meet the body requirements. Potato and sweet potato supply about 16% of ascorbic acid. A pound (404 g) of green chilli contains about 7 times as many 4040 mg of ascorbic acid found in a pound of Irish potato.

Vitamin D: It is known as Calciferol and, is a fat-soluble vitamin. Its deficiency may cause rickets in infants. A good supply of vitamin D is essential for proper bone formation and healthy teeth. It helps in the calcification of bones by proper

utilization of calcium (Ca) and phosphorus (P) salts. Green vegetables are rich sources of this vitamin.

Vitamin E: It is known as Tocopherol and, is also a fat-soluble substance. It is essential for reproduction and is an anti-sterility vitamin. It is found commonly in leafy vegetables like cabbage, lettuce and in vegetable oils.

Vitamin B_2: This is a growth-promoting vitamin which is water soluble. Deficiency of this vitamin in diet causes loss of appetite and weight, sore-mouth, pellagra disease, and alopecia. It is essential for growth and healthy skin. It is formed during the growth of the green plants and green leaves which are good sources of this vitamin.

Amino acids: These are the fatty acids in which the amino acids group takes the place of a hydrogen atom of the hydrocarbon radical. They are very essential for the growth and development. The amino acids composition of vegetable proteins show wide variations, but since these proteins are quantitatively unimportant in the human diet, the variations are without appreciable effect on nutrition.

Vegetables as sources of energy/carbohydrates

Vegetables such as potato, sweet potato, peas and dried seeds of beans are significant energy foods or sources of calories. Succulent roots, bulbs and tubers are also rich sources of carbohydrates. The use of vegetables should be greatly increased in quantity when a person is on a reducing diet.

Vegetables as sources of roughage/fibre

Roughage in diet aids in digestion and prevents constipation. Most vegetables, particularly the leafy ones such as spinach, lettuce, cabbage and Indian spinach, are characterized by high water content and high percentage of cellulose or fibre. When these vegetables and most of the root vegetables are eaten they improve the tone of the muscles, especially those of the bowels. Thus consuming green vegetables, is consuming cellulose and chlorophyll which help digestion. Vegetable stems, leaves, bulbs and roots yield a spongy mass on cooking, which not only satisfies appetite but also assists in pushing the food down easily through the digestive tract, thus acting as a laxative and preventing constipation.

Vegetables as sources of antioxidants

Apart from providing the nutrition, few vegetables are also used in curing some of the commonly occurring diseases in human beings, such as cough, respiratory problems, chest congestion etc. The curing properties of some of the vegetables are as follows:

(i) Garlic, *Allium sativum*, used as a condiment in India for various dishes contains 15 antioxidants, which prevent the accumulation of cholesterol in the blood vessels. *Ajoene*, an antioxidant, present in garlic dissolves clots and prevents them from forming. Garlic is known to kill more than 70 diseases causing bacteria, viruses, fungal pathogens and yeast. Garlic also helps in controlling respiratory problems such as bronchitis, nose and chest congestions and even emphysema.

(ii) Onion, *Allium cepa*, used all over the world, helps in controlling allergies,

fever and asthma. A folk preparation called as onion cough syrup is a remedy for respiratory problems.

(iii) Quercetin, an (*Asparagus*) antioxidant present in onion acts as a mild sedative and helps people relax and sleep. Green onions are rich in vitamin A. *Asparagus officinalis*, a green leafy vegetable, is a source of antioxidant, vitamin A, vitamin C and a substance called glutathione. Glutathione contains 3 amino acids and keeps eyes healthy by interfering with cataract formation. It is a good source of potassium (K) also, which keeps heart healthy by regulating its beating patterns and maintaining normal blood pressure. The B vitamin folate present in asparagus helps prevent neural tube defects.

(iv) Carrots (*Daucus carda*) are a natural and easy defense against heart diseases, strokes, many cancers, cataract, and even constipation. Carrot is considered as an immune system booster. It contains β-carotene, which is good for eyes health. Carrots supply antioxidants such as α-carotene, γ-carotene, lycopene and lutein, which prevents cancer.

(v) Tomato (*Solanum lycopersicum*) is thought of as a vegetable, but botanically classified as a fruit. One can consume tomato raw, steamed, fried, stewed or crushed. Tomato is rich in vitamin C and contains lycopene, a red carotenoid which acts as antioxidant, and protects from cardio-vascular disease and cancer. It also prevents developing precancerous cells of the cervix in women. Frequently eating tomato avoids the occurrence of stomach and lung cancer.

(vi) Spinach (*Spinacia oleracea*) is a green leafy vegetable, rich in vitamin A, present in the form of β-carotene. The antioxidants present in it help to prevent cancer, heart disease, and cataracts and boost the immune system. It contains alkaline, which helps smokers throw out their cigarettes as smoking habit, as nicotine is recirculated in the bloodstream, which diminishes cravings.

(vii) Sweet potatoes (*Ipomoea batatas*) are a good source of vitamin C and potassium. Very importantly, they contain β-carotene in higher quantities when compared with γ. The β-carotene, an antioxidant protects blood cholesterol from oxygen damage and avoids clogging of arteries. Celery contains a phytochemical known as 3-N-butylphthalide, which lowers the blood pressure and it is not found in other vegetables. It also helps in controlling stomach cancer.

Vegetables to counter the harmful effects of protein foods

Tissues of human body are alkaline, and it is essential that for good health, proper alkaline reserve is maintained in the body. Green vegetables counteract the harmful action of protein foods such as meat, egg etc., which disturb the alkaline reserve of the body by producing acidic substances. It is necessary, therefore, to use vegetables in abundance daily to counter the harmful effects of proteins. The vegetable crops should be more widely recognized and used not only because they supply both basic and accessory nutrients, and taste good, but also because they provide maximum quantity of food for the unit area planted, and further they grow faster.

CHAPTER 3

Vegetable Nutrition and Human Health

VEGETABLES play a vital role in Indian economy and sustain the livelihood of a large section of population directly or indirectly (Pandey, 2004). Vegetables are usually higher in productivity than the other crops. These crops can provide more food per unit time and area of land. With the increase in awareness with regard to quality of food and balanced diet, the proportion of vegetables on the plate in every meal is increasing, thereby decreasing the pressure on production and consumption of cereals among the people of the developing world. It is recognized that 1 kg of *palak* provides more nutrition and volume than 1 kg of rice (Nath and Dutta, 2004).

Vegetable, by definition, is a nutritional and culinary term denoting any part of a plant that is commonly consumed by human beings as food, but it is not regarded as a culinary fruit, nut, herb, spice, or grain. In common usage, vegetables include the leaves (e.g., lettuce), stem (e.g., asparagus), and roots (e.g., carrot) of various plants. But the term can also encompass non-sweet fruits such as seed-pods (beans), cucumber, squash, pumpkin, tomato, avocado, green pepper etc., even some seeds (peas and beans) that are easily softened by soaking (Anon., 2004b).

Vegetables are the major, low-priced, and sustainable source of nutrition for the masses. They are good source of fibre, carotenoids, vitamin C, folate, potassium, and other vitamins (Nath and Dutta, 2004). Leafy vegetables compliment as well as supplement to the protein rich diet from animal sources. Vegetables, apart from being rich in protein supply, more importantly, they supply the nutritionally essential amino acids, fatty acids, minerals, vitamins, and fibre (Swarup and Lian, 2004). New evidence proclaims that consumption of vegetables minimizes the risk of diverticulosis and chronic obstructive pulmonary diseases (Krishnaswamy, 2004). At the International Congress on Vegetarian Nutrition, held at California's Loma Linda University, it was reported that eating more fruits and vegetables can slow down, and perhaps reverse age-related declines in brain function, and in cognitive and motor performance (Fresco and Baudoin, 2004).

Nutrition is interpreted as the organic process by which an organism assimilates and uses food and liquids for normal functioning, growth and maintenance or it is the study of the relationship of food and drink to health and disease or it is the idea of an optimal balance of nutrients and whole foods, to enable the optimal performance of the body (Anon., 2004a). Therefore, vegetables play an important role in meeting the nutritional requirements of the human body for growth and efficient performance.

Uses of vegetables

Vegetables are commonly used after cooking, eaten raw and used as an ingredient in medicinal preparations. Almost all vegetables are cooked before consumption like potatoes, brinjal, gourds, cucurbits etc. Vegetables, which are consumed raw, are tomato, carrot, cucumber, little gourd, onions, cabbage etc. Vegetables are used to prepare some of the home-made medicines. Garlic is one such vegetable, when consumed helps in preventing stomach, colon, lung, skin and oesophageal cancers. It is also used as a remedy for cold and flu. Onion is another example, from which syrup is prepared, and used as a remedy to control respiratory problem (preparation of onion syrup: chop 5 to 6 onions and slowly simmer for 2 hr or so in a double boiler with about ½ cup of honey. Teas poons taken throughout the day help breakup congestion during cold and limit inflammation (Anon., 2001).

Nutritive value of different vegetables

Man needs a wide range of nutrients to perform various functions in the body and to lead a healthy life. The nutrients include proteins, fats, carbohydrates, vitamins, and minerals. These nutrients are chemical substances, which are present in the food we eat daily. Proteins, carbohydrates, and fats are referred to as proximate principles. They are oxidized in the body to yield energy, which the body needs. In plant foods, fibre (dietary fibre), which is an indigestive complex molecule, also contributes to the bulk and has some useful functions in the digestive tract. Vitamins and minerals do not supply energy but they play an important role in the regulation of the metabolic activity in the body. Minerals are also used for the formation of body structure and skeleton (Gopalan *et al.,* 2004). Besides providing the nutrition, few vegetables are also used in curing some of the commonly occurring diseases in human beings, such as cough, respiratory problems, chest congestion, etc. have been given earlier. The curing properties of some of the other vegetables are given below (Anon., 2001):

Beet roots are rich sources of vitamin B namely as folate, which is essential for preventing some forms of anemia and neural tube birth defects in babies. The folate present prevents the occurrence of cancer. It protects cells from mutation. Fibre content in the beet helps keep the intestinal tract running smoothly and potassium (K) helps keep the heart beating regularly and blood pressure normal.

Cabbage is used to prevent and heal ulcers. It contains a phytochemical called indole, which has the ability to shunt estradiol, a potent form of estrogen, into a safe form of estrogen, which helps in reducing estrogen related cancer.

Cauliflower is a natural cancer fighter, notably against breast and colon cancers. The cruciferous vegetables are rich in vitamin C, next to the citrus fruits. They also supply good amounts of fibre, folate and potassium.

Potato is another vegetable, which is commonly used all over the world. It has a mild estrogen activity, helps to protect from heart diseases and osteoporosis.

Consumption of vegetables

India is a continent with diverse climatic conditions suitable for growing varied types of vegetables. The different vegetables cultivated in India are potato, carrot,

brinjal, tomato, beans, beet root, radish, capsicum, knol khol, chow chow, onion, cucumber, snake-gourd, bottle-gourd, little-gourd, ridge-gourd, bitter-gourd, ash-gourd, clusterbean, amaranth, *methi*, coriander, curry leaves, asparagus, water-melon, muskmelon, okra, *palak*, tapioca, sweet potato, cabbage, cauliflower, peas, pumpkin, field bean, etc. In most of the developing countries in the Asian continent, the staple food is rice, but in the changing global scenario, the diet of the people living in Asian countries and other parts of the world is changing as the awareness of eating right food is playing an important role in every body's life. India stands second next only to China in production of vegetables.

Over the years, the production of vegetables in India has gradually increased. The production was 58.53 million tonne in 1991–92, 88.62 million tonne in 2001–02 and 156.325 million tonne in 2011–12 (NHB, 2011). Despite India's rapid economic growth, there are still 300 million people living below the poverty line and 75% of the poor live in rural areas. Normally 300 g vegetables consisting of root vegetables (90 g), green leafy vegetables (120 g) and legume vegetables (90 g) are required per person per day for maintaining a good health (Nawab Ali. 2011). Per capita consumption of vegetables in India is only about 86 g/day, compared with FAO's recommendation of 400 g/day (AVRDC, 2011).

As per the FAO statistics the daily per caput energy availability from vegetables in Indonesia was 2,785 kilo calories, in Iran, it was 2,644 kilo calories, and in India, it was 2,234 kilo calories. The daily per caput energy availability from vegetables in developing countries is high compared to the developed countries, as the people living in developed countries depend mostly on animal products to meet the daily energy needs (Anon., 2002b). The current per caput consumption of vegetables is highest in China (270 kg per year), followed by Singapore (120 kg), Myanmar (80 kg), the Philippines (55 kg), India (50 kg), Malaysia (49 kg) and Indonesia (40.6 kg). FAO recommendations for vegetable consumption per caput is 73 kg per year (Anon., 2011a).

Nutritional security and vegetables

Estimates and projections of hunger: Latest estimates indicate that 826 million people remained under-nourished in 1996–98: 792 million people in the developing world and 34 million in the developed world. The figures for 2015 indicate that the overall proportion of the developing countries' population that is undernourished will be half what it was in 1990–92, the base period for the World Food Summit target. But the number of undernourished people will still be around 70% of what it was in 1990–92. Overall, these outcomes would reflect the continuation of long-term declines in the prevalence of undernourishment in Asia, which began in 1969–71 in East Asia and a decade later in South Asia. In the world's 2 largest countries—China and India—slowing population growth and strong economic growth would bring significant increases in per caput food availability between 1996–98 and 2015. For these 2 countries combined, the prevalence of undernourishment is projected to decline from 16% in 1996–98 to 7% in 2015. Together they represent more than one-thirds of the world's population, so any change in their levels of under-nourishment has a large effect on world

averages (Source: Special Report: FAO/World Food Programme Crop and Food Supply Assessment Mission), Table 4.

Table 4. Projected trends in undernurishment in different countries

Countries	Population (%)			People (Million)		
	1996–98	2015	2030	1996–98	2015	2030
Sub-Saharan Africa	34	22	15	186	184	165
Near East/North Africa	10	8	6	36	38	35
Latin America and the Caribbean	11	7	5	55	45	32
China* and India	16	7	3	348	195	98
Other Asia	19	10	5	166	114	70
Developing countries	18	10	6	791	576	400

Source: Agriculture: Towards 2015/30; *Technical Interim Report, FAO*, April 2000
*Indicates?

The Asia and Pacific region experienced continued improvement alleviating chronic energy deficiency during the last 20 years, with the proportion of the population affected falling from 41 to 16% in East and South-East Asia and from 33 to 22% in South Asia. Total numbers declined in East and South-East Asia from 289 million to 258 million people, but South Asia experienced an increase from 237 to 254 million. To support an active health life, dietary energy must come from diverse food sources. Lack of food diversification gives rise to protein-energy malnutrition (PEM), which needs to be addressed through integrated food-based strategies using a community-based approach. Daily per caput energy availability in Asian countries is given in Table 5.

Table 5. Daily per caput energy availability (kilo calories) as compared with energy requirements in the Asian countries in 2000 A.D.

Country	Requirement	Total availability	Availability as% of requirement
Bangladesh	2,178	2,103	96.5
Bhutan	2,161	2,555 *	118.2
India	2,172	2,428	136.1
Nepal	2,177	2,436	111.9
Pakistan	2,106	2,452	116.4
Sri Lanka	2,210	2,405	108.8
Cambodia	2,152	2,070	96.2
China	2,274	3,029	133.2
DPR Korea	2,202	2,185	99.2
Mongolia	2,151	1,981	92.1

Source: FAO (RAP) 2001.
*Data for 1998; Daily per caput intake (*FAO-Nutrition Country Profile*, 1999).

Trends in energy requirements and food supplies in India: Between 1965 and 1995, the population in India almost doubled and it is projected to increase by 43% by 2025 (Table 6). The increase in energy requirements reflects the growing needs of the population. The energy requirements of the urban population increased by three-fold over 1965–95 and are projected to double by 2025. The rural population has increased at a lower rate. Its requirements have almost doubled between 1965 and 1995, and are projected to experience a 16% increase by 2025.

The per caput calorie availability falls short of the requirement in Bangladesh, Cambodia, DPR Korea and Mongolia. Therefore, food availability only just meeting the requirement level in a country must deprive large sections of the people of access to sufficient food. The access will improve with the rise in capacity

Table 6. Total population, urbanization rate, individual energy requirements and dietary energy supplies (DES) in 1965, 1995 and 2025

Year	1965	1995	2025
Total population ('000)	495,157	929,005	1,330,201
Percentage urban (%)	18.8	26.8	42.5
Per caput energy requirements (kcal/day)	2,119	2,163	2,203
Per caput DES (kcal/day) *	2,002	2,390	—

Source: FAO-Nutrition Country Profile - INDIA, 24 June 1998, FAO, Rome

building, people's participation, and incomes of the poorer sections of the people, which in turn, will give rise to greater food availability. It has been observed that when national average food availability is more than 20% above the requirement level, almost all people have purchasing capacity to at least buy food. Children form the largest vulnerable group experiencing energy deficiency and most of the undernourished children live in Asian countries. Most of the people in the world suffer from protein-energy malnutrition, iron (Fe) deficiencies, iodine (I) deficiency, and vitamin A deficiency and lower birth weight (Nandi and Bhattacharjee, 2004). As the life-style of the Asians is under transition, the blooming urban population does not require as much physical work as their rural counterparts. They also prefer a diverse diet with increased consumption of meat and pre-processed products. It is better to understand that a number of chronic diseases, such as obesity, diabetes, hypertension, and ischaemic heart diseases are associated with diet. More consumption of vegetables is the main concept recommended. They also demand year-round availability of diverse vegetables (Tsou, 2004).

Role of vegetables in human health

Vegetables are rich and comparatively an economical source of vitamins and minerals. They increase appetite and provide taste, palatability and fibre to the diet. They also contribute carbohydrate, protein and fat. Vegetables are beneficial to human health, specially against the degenerative diseases and also play a key role in neutralizing the acids produced during digestion and help in preventing constipation. Vegetables are good for Indians, specially the vegetarians representing 65–70% of total population of over 1.2 billion (Nawab Ali, 2011).

The WHO/FAO expert report on '*Diet, Nutrition and Prevention of Chronic Diseases*' emphasized the important role that fruits and vegetables could play in preventing major non-communicable diseases (NCD) such as cardio-vascular diseases and creative cancers. It is reported that non-communicable diseases, including cardio-vascular diseases (CVDs), diabetes, obesity, cancer and respiratory diseases, account for 59% of the 56.5 million deaths annually world-wide and for 45.9% of the global burden of disease (Nath *et al.*, 2008). Five of the ten leading global diseases burden risk factors identified by *World Health Report, 2002* – high blood pressure, high cholesterol, obesity, physical inactivity and insufficient consumption of fruits and vegetables–are among the major causes of these diseases. It has been found that fruits and vegetables consumed sufficiently

on a daily basis could help prevent major diseases such as CVDs and certain cancers. According to *World Health Report, 2002*, low fruit and vegetable intake is estimated to cause about 31% of ischaemic heart disease and 11% of stroke world-wide. The joint FAO/WHO expert consultation on diet, nutrition and the prevention of chronic diseases, recommended the intake of a minimum of 400 g fruits and vegetables per day (excluding potatoes and other starchy tubers), which prevents chronic diseases such as heart disease, cancer, diabetes and obesity. It also helps in prevention and alleviation of several micronutrient deficiencies, especially in less-developed countries (Nath *et al.*, 2008).

The FAO Statistical Database indicates that the total supply of fruits and vegetables available is 173 kg/person/year, which divides into 111.6 kg vegetables and 61.4 kg fruits. However, when a potential loss of 33% is taken into account, representing the loss from supply source to table, this availability is reduced to 115 kg/person/year (Anon, 2003a). To prevent the 33% loss of fruits and vegetables due to various reasons (such as transportation, storage, timely harvest, *etc.,*) and to increase the consumption of fruits and vegetables, there is a need to improve their supply and distribution systems for which more research and technology development is required. More knowledge is needed about many of the indigenous and under-utilized horticultural crops and their role in the rural household economies (Anon, 2004c). Thus, it is evident that fruits and vegetables are important for human health and nutrition, as they contain vitamins, essential micro-nutrients, fibre, vegetable protein, and bio-functional components. The world's demand for fruits and vegetable will increase with rising standards of living and the awareness of the health benefits of fruit and vegetables, dietary patterns will change and the consumption of fruits and vegetables per caput will increase. Fruit and vegetable production, easily undertaken by unskilled people, can play an important part in poverty alleviation and food security initiatives, providing employment opportunities and a source of income. Developing countries, who may find new opportunities for fruits and vegetables trade and earning foreign currency, which offer a comparative advantage in the context of globalization (Anon., 2003a). •

CHAPTER 4

Food Security and Vegetables

AROUND one billion people in the world do not have enough to eat, as majority of the population has no economic or social advancement. In India, there are 233 million hungry and malnourished people. On an average, 2 out of every 3 malnourished children in the world live in South and South-east Asian countries. There are 497 million hungry people living in Asia and the Pacific region. It is estimated that there would be 300 million under-fed children, women, and men by 2015 in Asia and the Pacific nations, if they fail to gear up the effort to reduce the hunger (Nath, 2004b). Three out of every four poor persons in the world live in India. The number of poor living in India has crossed 310 million, i.e. 50% more than in sub-Saharan Africa. As many as 40–60% of Indian children are undernourished, 60% women are anaemic and victims of diseases arising from anaemia. More than half of the world population suffering from hunger live in seven countries, namely China, India, Indonesia, the Philippines, Pakistan, Vietnam, and Bangladesh. As per the *World Development Report* (2003), the Asian region is marked by high incidence of poverty (Moily, 2004). Hunger causes illness and death, robs people of their potential to work and cripples children's learning capacity. It traps individuals in a vicious cycle of poor health that is passed on from one generation to the next, which is a fundamental violation of human rights. Therefore, the important challenge facing in the new millennium is to eliminate chronic hunger (Nath, 2004b).

Food security

The fundamental human rights stated by the Universal Declaration of Human Rights say, 'the right to food is a basic human right as well as a basic human need'. Thus providing food security to the growing population is the major and most important challenge in the present world. Food security is attained when all people, at all times, have the physical and economic access to sufficient safe and nutritious food, to be healthy and active (Nath, 2004b). Vegetables support food security.

Challenges of food security

As we all know that the world produces adequate food for everyone, but the unequal distribution has created a gap between the countries that produce food more than they consume and those countries with deficit production. A sustainable

equality can be attained by bridging the gap not by importing of food but by producing themselves. The production of cereals and other agricultural crops is sufficient, but it is not able to meet the diverse food requirement of the people (Nath, 2004 c). In the scenario described, food insecurity and malnutrition will persist in 2020 and beyond. It was projected that 135 million children under 5 years of age will be malnourished in 2020, a decline of only 15% from 160 million in 1995. According to another report (FAO, 1998; UNDP, 1999), current trend shows that another 1.5 billion people will be added to the population of developing Asian countries by 2025. This population growth will coincide with the increased demand for food, land, and water (Nath and Dutta, 2004).

Role of vegetables in food security

The increased production and consumption of horticultural crops, particularly vegetables, with their wide adoption and as provider of important nutrients offer promise for the future. Horticultural crops are higher in productivity than other crops. They provide more food per unit time and area of land. For example, hybrid cabbage and chinese cabbage yield up to 40 to 60 tonne/ha in an average growing period of 3 months. The more recent advances in technology, particularly hybrids and biotechnology have added value to this group of crops in term of efficiency and quality (Nath, 2004 c). Vegetable production is an important source of livelihood for the rural poor, as it provides alternative sources of income and increases opportunity for on-farm employment. In many developing countries, returns from vegetable production are twice the returns from rice crop. According to an FAO estimate, average world's annual vegetable production during the 1985–95 period was 489 million tonne. Therefore, a careful integration of the crop and vegetable production systems will be of critical importance for ensuring sustainable food security (Dar, 2004). Vegetable production provides farmers having the possibility to cultivate a small or even a very small piece of land, the possibility of obtaining an income, any time they bring their products to the market. Therefore, selling vegetables provides even a small farmer with the possibility of avoiding starvation and misery, besides the direct contribution to improve the health of urban people (Bozzini, 2004).

Community-based programmes

Some of the community-based initiatives have proved successful in different countries of the developing world, such as eating right food, improving food production, nutrition garden, promoting local food, processing and preserving food and education on nutrition (Nath, 2004b).

In the wake of horticultural crops gaining importance as a supplement to the food requirement and valuable nutrient provider, the FAO launched the Special Programme for Food Security (SPFS) in 1994 in Low-Income Food-Deficit Countries (LIFDCs) to empower small farmers, as well as poor families in urban areas, to provide food needs, to diagnose the constraints and opportunities, which they face and to identify, test and take viable, locally adapted and sustainable options. The horticultural crops particularly, vegetables played an important role in this programme in different countries. •

CHAPTER 5

Growth and Development of Vegetable Crops

VEGETABLES are grouped under herbaceous plants and grown for their edible parts, may be root, stem, leaf, flower, flower bud, fruit and seed or whole plant used for culinary purposes. All the edible parts of the vegetable crop plants contribute to the productivity of vegetable crops in terms of yield per plant or per unit area. The yield may be defined as the economic product harvested from domesticated plant's growth under managed environmental conditions (Adams, 1984). Crop physiologists and agronomists have recognized 2 kinds of crop yields, viz. economical yield and biological yield. Economical yield is the weight of plant portion having direct economic worth, whereas the biological yield is the total weight at harvest, of roots, stems, leaves, fruits or seeds, if any. The ratio of economical yield to biological yield is known as the harvest index (HI). This ratio varies according to the crops and varieties, from 0.25 (low) to 0.65 (high) (Adams, 1984). Plant parts of vegetable crops having economic worth have been mentioned by Adams (1984).

Edible parts of vegetable crops

The growth and development of vegetable plants play important role in the productivity of vegetable crops. Like other flowering plants, vegetables grow, bear flower and produce seed to complete their life-cycles. Once the seed sown in the soil, it germinates and seedling emerges from the soil, and there is continuous growth until plant completes its life-cycle. Growth is not easy to define because it is a complex phenomenon associated with numerous physiological processes. However, it may be defined as a permanent and irreversible increase in size and form, attended by an increase in weight (Dutta and Dutta, 1996). (Greuleach and Adams 1967) described growth as an increase in protoplasm, usually accompanied by an irreversible increase in size and weight and involving the division, enlargement and the differentiation of cells. Cell-division and cell enlargement account for the increase in size of a plant but different cell types, tissues and organs of the plant cannot occur without cell differentiation to perform various functions of the plant. So, differentiation can be defined as the process by which cells undergo biochemical and structural changes to perform specialized functions. Differentiation leads to morphogenesis. Morphogenesis is also known as development in which form or shape of cells and organs develops. Thus plant growth is accompanied by differentiation and morphogenesis. Two types of growth,

namely primary and secondary growth, are recognized in plant. Primary growth occurs at the tips of the shoots and roots and in lateral buds. Secondary growth takes place in the regions that have stopped elongation. e.g. the increase in dia of the stem and root. Both the types of growth are associated with zones in which cells are rapidly multiplying. These zones (tissues) are known as meristems which are of 2 types; (*i*) apical meristem, which gives rise to primary growth and (*ii*) lateral meristem, which gives rise to secondary growth.

The plant is made up of organs such as leaf, stem, root, flower and fruit. Each organ performs a particular task. These organs may be grouped as root-system (below the ground) and shoot system (above the ground). The shoot system consists of stem and leaf. The joint where a leaf is borne on the stem is called a node. The space between 2 nodes is termed as internode. Bud found at the leaf base between leaf and stem angle is called lateral bud or axillary bud, which develops into a branch. The bud found at the stem apex is called terminal bud, from where the new stem and leaf tissues are produced. Bud may be vegetative or reproductive. Vegetative bud develops into branches, whereas reproductive bud develops into flower, which is responsible for fruit and seed formation. The seed is a dormant undeveloped plant. It germinates under suitable conditions. During germination when plant begins to grow from seed it has 2 original organs, namely radicle and plumule. These organs form primary plant body. As the plant continues to grow, the primary plant organs develop into mature organs such as root, stem, leaf, flower, fruit and seed made up of permanent tissues.

Phases of growth and development

The growth and development of vegetable crops starting from the primary plant body to mature organs may be divided into 2 phases:

(*i*) vegetative and
(*ii*) reproductive phase.

Vegetative phase

This phase includes seed germination and development of root and shoot system (stem and leaves). Almost all vegetable crops show rapid growth period depending on the species and cultivars. From farmers point of view there are many advantages of the period of rapid vegetative growth as described below (Splittstoesser 1990):

(*i*) The plants can compete in a better way with weeds and other plants, and are able to receive more sunlight for photosynthesis, and ultimately more food produced which is reserved in the edible part resulting in high yield of beet, carrot, onion, radish, potato and sweet potato.

(*ii*) A build up of food materials in the leaves during vegetative growth are used in the flowering process.

(*iii*) In vegetables from which fruit is desired, larger plants can with-stand stresses of flowering much easier than small plants.

Root system

The root arises from the lower end (radical) of the embryo during seed germination. It grows downward into the soil and forms root system of the plant.

There may be formation of many types of root systems, viz. tap-root system, fibrous root system and adventitious root system. When the root system consists of mainly primary root with minimum branching is known as a tap-root system. Fibrous root system is formed when the lateral branches develop from the primary root. When the roots develop from the aerial portion of the stem, they are known as adventitious roots, e.g., prop roots of corm, roots developed from rhizomes, stolon and corms. Roots are critical for plant growth, because when plants are separated from their roots, most plants die. Roots have the following four main functions:

Anchorage. Roots penetrate deep and bind the soil in search of water and mineral. In doing so, they anchor the plant in one place for its entire life.

Absorption. They absorb large amounts of water and dissolved minerals from the soil.

Conduction. They transport water and dissolved nutrients to the shoot and photosynthates from shoot to root.

Food storage. Roots serve as food storage reservoirs. They store large amounts of energy reserves (food materials such as starch), e.g., sweet potato, sugar beet, carrot, radish and turnip.

Roots are modified as food storage reservoirs as mentioned below:

Development of edible roots. Roots of certain plants become swollen due to accumulation of foods in the form of sugars and starch. They enlarge and become fleshy—such as carrot, radish, turnip, beet root, sweet potato.

Modified tap-root for storage of food. In vegetables, botanically, there are 3 forms of root, viz., fusiform, napiform and conical form, as described below:

Fusiform. The root is swollen in the middle and gradually tapering towards the apex and the base, more or less, look like spindle-shaped in appearance. e.g. radish.

Napiform. The root is swollen at the upper part and becomes spherical and sharply tapering at the lower part. e.g., turnip and beet root.

Conical. The root is broad at the base and gradually tapering like a cone towards the apex, e.g., carrot.

Modified adventitious roots for storage of food. *Tuberous root* - This type of roots are produced by sweet potato. Roots developed from the branches of sweet potato plants become swollen and store food material. They are produced singly and do not have definite shape.

Shoot system

Shoot system arises from the upper end (plumule) of the embryo and develops from embryonic shoot apical meristem. Later on new leaves, branches and floral parts are originated from this shoot consisting of stem and leaves which are responsible for formation of plant canopy.

Stem: The stem is made up of specialized tissues such as xylem, cambium and phloem. Stem grows in length initiated by the apical meristem and diameter initiated by lateral meristems. Most of the vegetables are herbaceous and their stems are more succulent, less fibrous, more pithy and less tough than woody herbaceous plants. They are also not strong, hardy and rigid as woody stems. In

most of the vegetable crops, stems are aerial but in some vegetables, stems are modified for specific function and they grow as underground edible parts.

Stems together with nodes and internodes perform the following 4 important functions:

(*i*) They support leaves and help the formation of plant canopy.

(*ii*) When stems are green containing chlorophyll, photosynthesis occurs in them.

(*iii*) They conduct (transport) water and dissolved minerals in water from root to other parts of the plant and food material manufactured in the leaves by the process of photosynthesis to the roots.

(*iv*) They act as food storage organs, and mainly starch is accumulated in them.

Development of edible stem: Underground, modified, edible stems for food storage, in vegetable crops include, rhizomes, bulbs, corms and tubers.

Rhizomes. They are fleshy, underground modified stems and develop horizontally near the soil surface. They have short internodes and scaly leaves and produce roots along their lower surface. They are capable of reproduction and used as planting materials, e.g., ginger, turmeric.

Bulbs. Bulbs are rosette (very short), flattened, fleshy stems surrounded by layers of thickened, fleshy scaly leaves which store food materials. These bulbs are produced by some monocots for storage of food and reproduction, e.g. onion and garlic.

Corms. They are vertically oriented, globe-shaped, fleshy stems. They develop at the end of the stem and act as food storage organs and propagating parts. Corms have only a few thin leaves. They enable plants to survive winter, e.g., elephant foot yam and colocasia.

Tubers. These are enlarged, modified underground stems and act as storage organs and capable of reproducing plants. e.g. potato. Potatoes are tubers produced at the end of stolon. Stolon arises from the axil of lower leaf, grows horizontally outwards and ultimately swells up at the apex. It has all parts of the stem. A number of eyes are found on the surface of the tubers which grow into new plants. Adventitious roots are absent in tubers. Stem tubers can be easily differentiated from the root tubers which do not bear parts of the stem.

Modified aerial stem: In vegetable crops like knol-khol, aerial stem is swollen in spherical shape and it stores food material. Knobs of knol-khol are not used as propagating material.

Buds: Buds are undeveloped shoots or flowers composed of meristematic tissues and protected by modified leaf scales. There are 4 types of buds which develop into different organs:

Vegetative buds. They develop into shoots.

Flower buds. They open to produce flowers.

Mixed buds. They open to produce both shoots and flowers.

Adventitious buds. They develop in places where buds are not formed, such as bud developing on root cuttings.

Broadly there are 2 types of buds, apical buds and axillary buds. They may produce shoots or flowers. Apical buds are found at the stem apex and develop by apical meristems. They continue to grow until terminated into flowers. Axillary

buds are developed in the leaf axils at the stem nodes. They produce branches or flowers.

Leaf: Most prominent structure is the leaf. It develops like stem and is initiated by the apical shoot meristem. Leaves are attached at nodes and may be broad, flat, narrow and elongated or needle like. The leaves have the primary purpose of carrying on photosynthesis. Therefore, they are nutritious because they store water, salts, food materials and vitamins. The leaves of some plants such as spinach beet, spinach, fenugreek, lettuce, celery, parsley, cabbage, onion, and coriander have long been parts of our diets and favourite items in our salad. The leaves themselves are the primary organs of productivity in leafy vegetables for consumption. The six main functions of the leaves are:

1. Manufacturing food- The main function of leaves is to manufacture food through the process of photosynthesis in the presence of light.
2. Being broad and flat they are exposed to the maximum sunlight needed for photosynthesis.
3. Being thin, there is little volume and respiration therefore, it is at a minimum.
4. They act as food storage organs as in onion, garlic and cabbage.
5. They get-rid of excess of water through transpiration.
6. Other functions are reproduction flower and fruit formation root formation, climbing and protection.

Reproductive phase

The vegetative phase is terminated by reproductive phase in most of the vegetable crops. After completion of vegetative growth (development of roots, stems and leaves), reproductive phase takes place which consists of formation and development of flower buds, flowers, fruit and seed or enlargement and maturation of storage structures such as fleshy stems and roots. The important processes associated with the reproductive phase are as under (More, 1994):

(i) The maturation and thickening of tissues and fibres laid down during vegetative phase.
(ii) Production of plant growth regulators necessary for the development of flower bud primordia.
(iii) Development of flower buds, flowers, fruits and seeds or the development of storage organs (bulbs, storage roots and tubers etc.).

There is a gradual transition from vegetative phase to reproductive phase. The stimulus translocated from leaves to the meristem causes transformation of vegetative state to flowering state. Once the plants become vegetatively matured, they are induced to flower. Flowering consists of 3 phases, viz., (*i*) induction, (*ii*) initiation, and (*iii*) development.

Temperate vegetables or temperate varieties of certain vegetables require specific day-length and low temperature for flower induction and initiation. Whereas, most of the tropical and sub-tropical vegetables do not require these conditions and they are of self-induced flowering in nature such as beans, peas, tomato, peppers and cucumber. When they reach a certain morphological maturity, they flower. When flowers have fully developed, pollination, fertilization and fruit setting take place. Once the fruit has set, the fruit and other associated tissues

begin to grow and food materials move from other parts of the plant into these developing fruit tissues.

Flower: It is a reproductive organ essential for fruit and seed production. Flowers and flower parts of many vegetables such as cauliflower, broccoli, pumpkin, drumstick are edible and cooked as vegetable.

Fruit: A fruit is a mature ovary with associated parts formed after pollination and fertilization. It is a seed-bearing organ. Pollination and fertilization provide a stimulus to fruit set and seed development. Fruits of many vegetable crops are edible and eaten as vegetables.

Seed: It is a mature ovule consisting of 3 basic parts, embryo (miniature plant), cotyledon (food storing organ) and seed coat (protective covering). The embryo is a miniature plantlet formed within the seed from the fusion of male and female gametes during fertilization. The cotyledons and endosperm act as food storage organs, storing food in the form of starch, fat and protein. Vegetables like peas are grown for their immature edible seeds.

Shoot growth pattern

Depending on the nature of growth characteristics (habits) of species and varieties, vegetable crops exhibit mainly 2 types of shoot growth, namely determinate and indeterminate growth.

Determinate growth: Plants of some vegetable crops form flower buds (inflorescence) at the primary shoot terminals after a certain period of vegetative growth and further growth is stopped. The primary shoot terminates into inflorescence (flower cluster) and side shoots continue to develop. When further growth is ceased, plants become dwarf and bushy. e.g., bush bean, snap bean and some varieties of tomato.

Indeterminate growth: Primary shoot does not terminate into inflorescence at all and continues to grow till suitable growing conditions are available. The shoot terminal remains vegetative. Plants bear flowers laterally along the stem in the leaf axils, e.g., pole bean and some varieties of tomato.

Life-cycle of vegetable crops

On the basis of completion of growth and development, vegetable crops can be divided into 3 groups, viz., annuals, biennials and perennials. It must be known that all vegetable crops are fast-growing herbaceous plants. Like other flowering plants they produce flowers, fruits and seeds to complete their life-cycle.

Annuals: Annual crops complete their life-cycle in one growing season. In the annual vegetables, once the seed germinates and seedling emerges from the soil, there is a continuous growth and development until the plant completes its life-cycle, e.g., amaranth, brinjal, chilli, cowpea, cucumber, clusterbean, coriander, fenugreek, muskmelon, mustard, okra, green pea, pumpkin, tomato, spinach beet, squash, sweet corn, watermelon, ridge-gourd, sponge-gourd, bitter-gourd, bottle-gourd, snap-gourd, snake-gourd, spinach, chard, french bean, round gourd.

Biennials: Biennial vegetable crops require 2 growing seasons to complete their life-cycles. Plants have vegetative growth during the first growing season and produce flowers, fruits and seeds in the next (second) growing season. Most

of the annuals and biennials produce flowers, fruits and seeds only once before the plants die, e.g., beet, broccoli, cabbage, carrot, cauliflower, knol-khol, onion, radish, turnip, kale, lettuce (head type), garlic, potato, sweet potato, ginger, turmeric, and leek.

Perennials: Perennial vegetable crops remain alive and productive for several growing seasons or years. They produce flowers, fruits and seeds many times till the plants are alive. e.g., asparagus, artichoke, elephant foot yam, yams, pointed-gourd, spine-gourd, ivy-gourd, sweet-gourd, drumstick, winged bean, taro (*arvi*), cassava, chow-chow.

Viability of vegetable seeds stored under cold conditions varies from crop to crop. The seeds of onion and pea are viable for one year; seeds of okra, and onion are viable for two years; seeds of asparagus, beans, carrot, leek and sweet pepper are viable for three years; seeds of beet, chard, mustard, pumpkin and tomato are viable for four years; seeds of cabbage, kale, cauliflower, brinjal, knol-khol, lettuce, muskmelon, radish, turnip, spinach, and watermelon are viable for five years (Singh, 1997). ●

CHAPTER 6

Classification of Vegetable Crops

THERE are many vegetables and their different parts are used for consumption. They are botanically different and their climatic and cultural requirements are different. Vegetable crops are classified on the basis of botany, temperature requirement/hardiness, seasons of cultivation, edible parts used, life-cycle of the vegetable crops, major climatic regions and cultural requirements/ methods of culture.

Botanical classification

This method of classification is based on botanical relationships of crops in relation to cytology, morphology, taxonomy and crossability. This method is the favoured method for botanists, taxonomists and plant breeders. This system groups the plants into genera including class, family, genus, species and subspecies. Although this information is extremely useful to those interested in plant breeding and improving the plant lines, it is often of little use to growers because the cultural requirements of plants can vary greatly between genera. This is useful to breeder for crop improvement and seed producer for deciding isolation distance. Some plants do however have similar cultural requirements the most notable of these is the Solanaceae and Cucurbitaceae families. The cultural requirements may vary, e.g., solanaceous crops such as tomato, potato, chilli and brinjal, have similar cultural requirements. At the same time cucurbitaceous crops have similar cultural requirements and common pests and diseases. Botanical name avoids confusion in name as common names are different but scientific names are common all over world. It is for this reason that when grouping plants according to their *'cultural requirements'* horticulturists have grouped solanaceous and cucurbitaceous crops in their own distinct groupings. It gives information on class, family, genus, species, variety, etc. *e.g.,* Solanaceae family: Potato, brinjal, chilli; and Cucurbitaceae family: Melons, pumpkins, gourds. This classification is not useful to growers. Thus botanical classification is useful to breeders, seed producers, students and to avoid confusion in common name.

All the vegetable crops belong to the Division Spermatophyta, the Class Angiospermae and the Sub-class Monocotyledoneae or Dicotyledoneae, are mentioned as under:

Class:Monocotyledoneae

Family: Liliaceae

Asparagus (*Asparagus officinalis* L.)

Family: Poaceae/Gramineae

Baby corn/Sweet corn (*Zea mays* L.)

Family: Dioscoreaceae

Yams (*Dioscorea* spp.)
Greater yam (*Dioscorea alata* L.)
Lesser yam (*Dioscorea esculenta* L.)
White yam (*Dioscorea rotundata* L.)

Family: Araceae

Tannia [*Xanthosoma sagittifolium* (L.) Schott.]
Taro [*Colocasia esculenta* (Linn.) Schott.]
Elephant foot yam (*Amorphophallus companulatus* Blume.)

Family: Alliaceae

Onion (*Allium cepa* L.)
Garlic (*Allium sativum* L.)
Leek (*Allium porrum* L)

Class: Dicotyledoneae

Family: Compositae/Asteraceae

Globe artichoke (*Cynara scolymus* L.)
Jerusalem artichoke (*Helianthus tuberosus* L.)
Lettuce (*Lactuca sativa* L.)

Family: Umbelliferae/Apiaceae

Parsnip (*Pastinaca sativa* L.)
Indian pennywort (*Centella asiatica* L.)
Parsley [*Petroselinum crispum* (Mill.) Nym.]
Celery (*Apium graveolens* var *dulce* L.)
Coriander (*Coriandrum sativum* L.)
Carrot (*Daucus carota* L.)

Family: Brassicaceae/Cruciferae

Radish (*Raphanus sativus* L.)
Turnip (*Brassica rapa* L.)
Rutabaga [*Brassica napobrassica* (L.) Mill.]
Cabbage (*Brassica oleracea* var. *capitata* L. f. *alba* DC)
Brussels sprouts (*Brassica oleracea* L. var. *gemmifera* DC)
Cauliflower (*Brasssica oleracea* var. *botrytis* L.)
Broccoli (*Brassica oleracea* L. var. *italica*)

Knolkhol (*Brassica olearacea* L. var. *gongylodes* L.)
Seakale (*Crambe maritima* L.)
Mustard greens [*Brassica juncea* (L.) Czernj & Cosson]
Kale (*Brassica oleracea* L.var. *acephala*)

Family: Amaranthaceae

Water amaranth [*Alternanthera sessilis* Linn.]
Amaranth (*Amaranthus* spp.)
Garden beet (*Beta vulgaris* L.)
Chard (*Beta vulgaris* subsp. *cicla*)
Spinach beet (*Beta vulgaris* var. *bengalensis* Hort.)
Spinach (*Spinacia oleracea* L.)
Wild spinach (*Chenopodium album* L.)
Quinoa (*Chenopodium quinoa*)
Orach (*Atripex hortensis* L.)

Family: Leguminosae/Fabaceae/Papilionaceae

French bean (*Phaseolus vulgaris* L.)
Dolichos bean (*Lablab purpureus* (L.) Sweet (Syn. *dolichos lablab* L)
Cowpea [*Vigna unguiculata* subspecies *sesquipedalis* (L.) Fruw.]
Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]
Winged bean [*Psophocarpus teragonolobus* (L.) DC.]
Lima bean (*Phaseolus lunatus* L.)
Broad bean (*Vicia faba* L.)
Soybean [Glycine *max* (L.) Merr.]
Garden pea (*Pisum sativum* L.)
Scarlet runner bean (*Phaseolus coccineus* L.)
Velvet bean [Mucuna pruriens (L.) DC. var. utilis]
Agathi [*Sesbania grandiflora* (L.) Poiret.]
Fenugreek (*Trigonella foenum-graecum* L.)
Yam bean [*Pachyrrhizus erosus* (L.) Urb.]

Family: Cucurbitaceae

Musk melon (*Cucumis melo* L.)
Snap melon (*Cucumis melo* L.var. *momordica.*)
Water melon (*Citrullus lanatus* (Thunb.) Mnasf.)
Round melon [*Praecitrullus fistulosus* (Stocks) Pangalo]
Long melon (*Cucumis melo* var. *utilissimus* Duth. & Full.)
Pumpkin (*Cucurbita moschata* Poir. and *Cucurbita maxima* Dusch.)
Summer squash (*Cucurbita pepo* L.)
Ash gourd [*Benincasa hispida* (Thunb.) Cogn.]
Snake gourd (*Trichosanthes anguina* L.)
Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]
Sponge gourd/Smooth gourd (*Luffa cylindrica* Roem.)
Ridge gourd (*Luffa acutangula* Roxb.)
Bitter gourd (*Momordica charantia* L.)

Cucumber (*Cucumis sativus* L.)
Gherkin (*Cucumis sativus* L.var. *anguria*)
Pointed gourd (*Trichosanthus dioica* Roxb.)
Ivy gourd (*Coccinia grandis* L.)
Chow chow [*Sechium edule* (Jacq) Swartz.]

Family: Solanaceae
Tomato (*Solanum lycopersicum* L.; syn: *Lycopersicon esculentum* Mill.)
Brinjal (*Solanum melogena* L.)
Chilli (*Capsicum annuum* var. *longum* and *accuminatum* L.)
Sweet pepper (*Capsicum annuum* var. *grossum* L.)
Potato (*Solanum tuberosum* Li.ssp. *tuberosum*)
Black nightshade (*Solanum nigrum* L.)

Family: Labiatae
Coleus potato (*Coleus parviflorus* L.)

Family: Zingiberaceae
Ginger (*Zingiber officinale* Roscoe)

Family: Portulocaceae
Waterleaf [*Talinum fruticosum* (L.) Jussieu.]
Portulaca (*Portulaca oleracea* L.)

Family: Polygonaceae
Rhubarb (*Rheum rhaponticum* L.)
Sorrel (*Rumex vesicarius* L.)
Buck wheat (*Fagopyrum tataricum* Gartn.)

Family: Hydrophyllaceae
Pacific waterleaf (*Hydrophyllum tenuipes* Heller.)

Family: Malvaceae
Okra (*Abelmoschus esculentus* L. Moench)
Kenaf [(*Hibiscus cannabinus* L.; Syn. *H. sabdariffa]*

Family: Convolvulaceae
Sweet potato (*Ipomoea batatas* L.)
Water spinach (*Ipomoea aquatica* Forsk.)

Family: Euphorbiaceae
Cassava (*Manihot esculenta* Crantz.)
Sweet leaf (*Sauropus androgynous* L.)

Family: Moringaceae
Drumstick (*Moringa oleifera* Lam.)

Family: Rutacece
Curry leaf [*Murraya koenigii* (L.) Spreng.]

Family: Moraceae
Breadfruit (*Artocarpus altilis* L.)

Family: Basellaceae
Indian spinach (*Basella* sp. L.)

Family: Labiatae
Mint (*Mentha arvensis* L.)

Family: Tetragoniaceae/Aizoaceae
New Zealand spinach (*Tetragonia expansa* Murr.)

Family: Nyctaginaceae
Pisonia (*Pisonia grandis alba* R.Br.)

Classification based on temperature requirement/hardiness

Vegetables are grouped as hardy or tender on the basis of tolerance to frost, tolerance to lower temperature. This gives information on season of growing, i.e., cool season crops or warm season crops. This classification is not useful to growers.

Cool season crops

Hardy. Asparagus, broccoli, brussels sprouts, cabbage, collard, garlic, kale, kohl rabi, leek, mustard, onion, pea, radish, rhubarb, rutabaga, spinach, turnip.

Semi-hardy/Half-hardy. Beet, carrot, cauliflower, palak, celery, chard, chinese cabbage, globe artichoke, Jerusalem artichoke, lettuce, parsnip, potato

Warm season crops

Tender. Cowpea, snap bean, soybean, sweet corn, tomato

Very tender. Cucumber, cantaloupe, brinjal, musk melon, Lima bean, okra, chilli, sweet pepper, pumpkin, squash, sweet potato, water melon, amaranth.

Classification based on season of cultivation

This is an important classification keeping in view the convenience of growers as well as students of agriculture based on the distinct growing seasons prevailing in most of the plain areas of India. The vegetables have been classified for their best growth, development and production. In other words, they are season specific. A group of vegetables are considered specific to a particular growing season, if their best production coincides with that period. The distinct growing seasons in the plains of India are as under:

Summer crops

The summer or spring season prevails from February to June in the northern plains and from January- May in the southern plains and the crops grown are

muskmelon, watermelon, long melon, snap melon, round melon, bottle-gourd, bittergourd, snake gourd, ash gourd, ridge-gourd, sponge-gourd, pumpkin, summer squash, cucumber, okra/bhindi, tomato, brinjal, sweet pepper, chilli, cowpea, cluster bean, amaranths and portulaca.

Rainy or **kharif**-*crops*

The rainy season prevails from June to October. However, the rainy season (June to September) has slight variation in different regions depending on the time of the rains and the crops grown are round melon, bottle gourd, bitter-gourd, snake-gourd, ash-gourd, ridge gourd, sponge-gourd, pointed gourd, pumpkin, okra/*bhindi*, tomato, brinjal, sweet pepper, chilli, coccinia, chow-chow, cowpea, clusterbean and dolichos bean.

Winter or **rabi**-*crops*

The winter season (October- January) is more or less the same throughout the plains in India and vegetables are cabbage, cauliflower, knol-khol, Brussels sprouts, sprouting broccoli, radish, turnip, carrot, beet root, *methi*, spinach beet, lettuce, onion, garlic, French bean and peas.

Some of the vegetables can be grown in both summer and rainy seasons, though in a specific sense they might have been grouped under a particular season for maximum performance. In some areas like Bengaluru, these seasons are not very distinct and hence crops like tomato, brinjal, sweet pepper, chilli, okra and gourds can be grown almost through out the year.

Classification based on the edible parts used

From roots to fruits different parts of vegetables are consumed. Based on the plant parts used/consumed the vegetable crops are categorized into different groups. This classification is not of much use, because of the differences in the cultural requirements of each crop in a particular group. Based on the edible parts used, vegetable crops are classified as under:

Underground parts

Roots: Beet root, carrot, parsnip, radish, rutabaga, turnip.

Tuber: Potato, sweet potato, Jerusalem artichoke.

Bulbs: Garlic, leek, onion.

Corm: Taro.

Above ground parts

Stems: Asparagus, knol-khol, amaranth, spinach, cauliflower.

Leaves: Brussels sprout, cabbage, celery, chard, Chinese cabbage, collard, kale, lettuce, spinach, amaranth, and fenugreek.

Flowers/Floral parts: Broccoli, cauliflower, globe artichoke.

Immature fruits: Cucumber, eggplant, okra, snap bean, summer squash, sweet corn, bottle-gourd, ridge-gourd, Ivy-gourd, bitter-gourd, snake-gourd, chow-chow.

Mature fruits: Muskmelon, cantaloupe, sweet pepper, poded pea, pumpkin, tomato, watermelon, winter squash.

Seeds: Cowpea, garden pea, soybean, Lima bean.

Classification based on life-cycle of vegetable crops

Like other flowering plants vegetable crops produce flowers, fruits and seeds to complete their life-cycle. It must be known that all vegetable crops are fast growing herbaceous plants. On the basis of completion of growth and development, vegetable crops can be divided into 3 groups, viz. annuals, biennials and perennials.

Annuals: Annual crops complete their life-cycle in one growing season. In the annual vegetables, once the seed germinates and seedling emerges from the soil, there is a continuous growth and development until the plant completes its life-cycle. e.g., amaranth, brinjal, chilli, cowpea, cucumber, clusterbean, coriander, fenugreek, musk melon, mustard, okra, green pea, pumpkin, tomato, spinach beet, squash, sweet corn, water melon, ridge gourd, sponge gourd, bitter gourd, bottle gourd, snap melon, snake gourd, spinach, Swiss chard, French bean, round gourd, cantaloupe, lettuce, snap bean, soybean, spinach, sweet corn, water melon.

Biennials: Biennial vegetable crops require 2 growing seasons to complete their life-cycle. Plants have vegetative growth during first growing season and produce flowers, fruits and seeds in the next (second) growing season. Most of the annuals and biennials produce flowers, fruits and seeds only once before the plants die, e.g., beet root, broccoli, cabbage, carrot, cauliflower, knol-khol, onion, radish, turnip, kale, lettuce (head type), garlic, potato, sweet potato, ginger, turmeric, leek, brussels sprout, celery, chard, collard, leek, parsnip and rutabaga.

Perennials: Perennial vegetable crops remain alive and productive for several growing seasons or years. They produce flowers, fruits and seeds many times till the plants are alive, e.g., asparagus, artichoke, elephant foot yam, yams, pointed gourd, spine gourd, ivy gourd, spiny bitter gourd/sweet gourd, drumstick, winged bean, taro, tapioca, and chow-chow.

Classification based on major climatic regions

Based on the ability of the plants to flower, fruit and produce seeds in different regions of the world, the vegetables crops have been classified into 3 major groups:

(i) Temperate vegetable crops

'Temperate region' is typically a region north or south of the equator, outside of the tropical zones. This region experiences very low temperatures in winter to very high temperatures in summer with copious amounts of rainfall. Jammu and Kashmir, Himachal Pradesh, Uttarakhand, fall under this region.

(ii) Subtropical vegetable crops

'Subtropial region' is a climatic zone characterized by hot summers and mild to cool winters. Rajastan, Delhi, Punjab, Uttar Pradesh, Bihar, Meghalaya, Asom, Nagaland, Manipur, Tripura, fall under this region.

(iii) Tropical vegetable crops

"Tropical region" is a non-arid climatic region in which all 12 months have mean temperatures above 18 °C. Unlike the extra-tropics, where there are strong

variations in day-length and temperature, with season, tropical temperature remains relatively constant throughout the year and seasonal variations are dominated by precipitation. Gujarat, Madhya Pradesh, Odisha, West Bengal, Mizoram, Maharashtra, Andhra Pradesh, Goa, Karnataka, Tamil Nadu and Kerala, fall under this region.

In the case of temperate crops, the plants require temperate climate or extreme winter to be able to flower and produce seeds. Here, these crops can be grown for vegetable both in the tropical and temperate regions but it would produce seeds wherever temperate climate prevails. For example, the cabbage is able to produce excellent head for vegetable in tropical plains but normally fails to produce seeds there. It produces seeds freely in the hills where temperate climate prevails. Similarly, cauliflowers have been grouped now into 4 maturity groups. Varieties of first 3 maturity groups, known as Indian cauliflowers, can produce seeds successfully in plains, while for the fourth maturity group ('Snow-ball' type), temperate climate is required for seed production though it is also cultivated successfully in tropical and sub-tropical regions during winter. In some crops like carrot, radish and turnip, there is a great variation among the varieties regarding their adaptability. The exotic or temperate varieties require temperate climate to produce seeds, whereas the tropical or Asian varieties produce seeds freely in the plains.

There is another important criterion on which the crops have been classified. In regions where frost is a common feature during winter, some of the crops which would have grown otherwise fail to grow. This is of utmost importance in the tropical plains. It is possible to grow tomato or brinjal or gourds during the winter in the plains of eastern and southern states, but in north-western states this is not possible because of the frost which kills the plants. Tropical crops flower, fruit and produce seeds freely in the warm or tropical climate.

Classification-based on cultural requirements

In this method, all those crops having similar cultural requirements are grouped together; they are botanically different. This classification has practical utility for vegetable growers. In this method, one can generalize cultivation practices for one group and thus avoid repetition individually for all crops. For the growers this is probability the most practical system of classification as it is based on essential methods of culture. That is, if a crop has similar climatic requirements and cultivation requirements, then such crops are grouped together. This grouping can often mean that crops grouped under the same heading may be botanically divergent. In some cases they are botanically also similar, *e.g.*, cucurbitaceous crops/cucurbits and solanaceous crops. Classification based on cultural practices has been proved most adaptable in field situations. On the basis of methods of cultivation, the vegetable crops are grouped as under:

Solanaceous vegetables

Tomato, brinjal, chilli, and sweet peppers.

Cucurbitaceous vegetables

Watermelon, muskmelon, longmelon, roundmelon, cucumber, pumpkin,

summer squash, ash-gourd, cucumber, gherkin, bitter-gourd, bottle-gourd, ridge-gourd, sponge-gourd, snake-gourd, Ivy-gourd, pointed-gourd, chow-chow.

Legume vegetables

French bean, dolichos bean, vegetable cowpea, winged bean, cluster bean, garden pea, lima bean, broad bean, vegetable soybean, sword bean, jack bean.

Root crops

Carrot, beet root, turnip, radish, parsnip, rutabaga, horse radish.

Bulb crops

Onion, garlic.

Tuber crops

Potato, sweet potato, tapioca, yams.

Leafy vegetables

Spinach beet, spinach, mustard greens, chard, fenugreek, amaranth, Indian spinach.

Cole crops

Cabbage, cauliflower, broccoli, brussels sprouts, knolkhol, kale, chinese cabbage.

Salad crops

Celery, lettuce, cress, parsley, baby corn.

Perennial vegetables

Asparagus, drumstick, curry leaf, artichoke, Jerusalem artichoke.

This method of classificatin has been largely used in almost all textbooks and has been followed in this book also. The vegetables described in this book have been dealt with under the above mentioned groups.

CHAPTER 7

Modes of Reproduction in Vegetable Crops

SUCCESSFUL production of a crop depends on a thorough knowledge of the reproductive process of a particular crop. The techniques of multiplication must take into account several features of reproduction: whether it is sexual, asexual, or a combination of the two, the nature of floral structures, the amount of pollen transfer, the degree and means of self-incompatibility, and the effect of inbreeding on vigour. For most purposes the important consideration to the seed producers is the extent of cross-pollination. It is, therefore, necessary that before engaging in seed production, a producer must acquaint himself with the following details of reproduction in a particular crop:

Methods of reproduction

In vegetable crop plants the method of reproduction may be broadly grouped into 2 categories: sexual and asexual or vegetative.

Sexual reproduction: Sexual reproduction involves fusion of male and female gametes to form a zygote and the zygote develops into a new plant. All self-pollinated and cross-pollinated vegetable crops are in this group:

A sexual or vegetative reproduction: Asexual reproduction does not involve fusion of male and female gametes. New plants are developed from vegetative parts of the plant or may arise from embryos that develop without fertilization. In nature, a new plant develops from a portion of the plant body. This may occur through modified underground and sub-aerial stems, bulbils, cuttings and grafting. As for example, taro, pointed gourd, potato etc., are reproduced through asexual means.

The main difference between sexual and asexual reproduction is that in sexual reproduction both parental sexes are concerned, while in asexual reproduction one parent or one sex is concerned.

Modes of pollination

Pollination refers to the transfer of pollen-grains from anther to stigma of a flower. Pollen from an anther may fall on stigma of the same flower leading to self-pollination or autogamy. When pollen from flowers of one plant are transmitted to stigma of another plant, it is known as cross-pollination or allogamy. A third situation, geitonogamy results when pollen from a flower of one plant falls on the stigmas of the other flowers of the same plant, e.g., maize.

Self pollinated vegetable crops: Many cultivated vegetable species reproduce

by self pollination. These species, as a rule, have hermaphrodite flowers. But in most of these species, self-pollination is not exclusive and cross-pollination may occur from 5 to 50%. The degree of cross-pollination in self-pollinated species is affected by several factors, namely variety, environmental conditions like temperature, humidity, wind, location and abundance of pollinating insects. However, the essential conditions for self-pollination are:

Bisexuality: In this both male and female reproductive organs are present in the same flower. Without this condition self-pollination is never possible.

Homogamy: This is the condition in which the anthers and the stigmas of a bisexual flower mature at the same time resulting in self-pollination.

Cleistogamy: In this condition the bisexual flowers never open and therefore, the self-pollination is only the way of pollination, e.g., lettuce.

Examples: Tomato, lettuce, parsnip, peas and dwarf bean.

Cross pollinated vegetable crops: The majority of the cultivated vegetable species are cross-pollinated crops. Cross pollination may occur both in bisexual and unisexual flowers, but it is the rule in unisexual flowers. Nature favours cross-pollination and the two agencies which help in bringing cross-pollination in flowers are, air (Anaemophily- e.g., amaranths, spinach, beet root) and insects (Entomophily- e.g., All cucurbits, all brassicas, onion, carrot).

There are many reasons for which cross-pollination takes place in the vegetable crops, some of which are listed below:

Decliny: Decliny or unisexuality is the condition where the plants are dioecious(unisexual) which enable them to cross-pollinate. The flowers either staminate (male) or pistillate (female) occur on the same plant or on different plants, e.g., cucumber, watermelon, pumpkin, squash, asparagus, sweet corn, lvy-gourd.

Dichogamy: The stamens and pistils of hermaphrodite flowers may mature at different times facilitating cross pollination, e.g., sweet corn, sugar-beet, etc.

Self incompatibility: It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant, e.g., cabbage, cauliflower, mustard, cole crops, root crops.

Male sterility: Male sterility refers to the absence of functional pollen-grains in otherwise hermaphrodite flowers. Male sterility is not very common in natural populations but is of great value in production of hybrid seed.

Examples for cross pollinated crops: Cabbage, cauliflower, broccoli, brussel's sprouts, knol-khol, carrot, radish, *beet-root, *spinach, cucumber, musk-melon, water-melon, pumpkin, summer squash, bitter-gourd, bottle-gourd, ridge-gourd, sponge-gourd, snake-gourd, pointed-gourd, ash-gourd, amaranths, onion etc.

* Wind pollinated crops

Often cross-pollinated vegetable crops: In some commonly self-pollinated vegetable crops, cross-pollination occurs about 5% and may reach up to 50%. Such species are generally known as often cross-pollinated crops. e.g., brinjal, okra, chilli, sweet pepper.

Safeguarding the seed fields or plants from foreign contamination through extraneous pollen transmitted by insects or transported by wind is essential for the production of pure seeds. Therefore, one should know the crossing patterns of different vegetables e.g., some cucurbitaceous crops, and cruciferous crops. ●

CHAPTER 8

Types of Vegetable Farming

VEGETABLE farming is growing of vegetable crops, primarily for use as human food. Vegetable growing/farming/gardening ranges from small patches of crops, producing a few vegetables for family use or marketing, to the great, highly organized and mechanized farms common in the most technologically advanced countries. There are 4 main systems of vegetable farming based on (1) production of vegetables for the fresh market, (2) production of vegetables for processing, i.e. canning, freezing, dehydration, and pickling, (3) production of vegetables to obtain seeds for planting material production and (4) production of organic vegetables (Choudhury, 1996; Warid, 2011).

Vegetable farming for the fresh market

This system/type of vegetable farming is normally divided into home/kitchen gardening, market gardening, truck farming, floating gardening and protected gardening/vegetable forcing.

Home/kitchen gardening: Home gardens are found in many humid and sub-humid parts of the world. They are sometimes called backyard or kitchen gardens. These gardens have an established tradition and offer great potential for improving household food security and alleviating micronutrient deficiencies. Gardening can enhance food security in several ways, most importantly through: (*i*) direct access to a diversity of nutritionally rich foods; (*ii*) increased purchasing power from savings on food bills and income from sales of garden products; and (*iii*) fallback food provision during seasonal lean periods. One of the easiest ways of ensuring access to a healthy diet that contains adequate macro and micronutrients is to produce many different kinds of foods in the home garden. This is especially important in rural areas where people have limited income earning opportunities and poor access to markets. Home gardens are also becoming an increasingly important source of food and income for poor households in periurban and urban areas.

A well developed home garden has the potential, when access to land and water is not a major limitation, to supply most of the nonstaple foods that a family needs everyday of the year, including roots and tubers, vegetables and fruits, legumes, herbs and spices. Roots and tubers are rich in energy and legumes are important sources of protein, fat, iron and vitamins. Green leafy vegetables and yellow or orange coloured fruits provide essential vitamins and minerals,

particularly folate, and vitamins A, E and C. Vegetables and fruits are a vital component of a healthy diet and should be eaten as part of every meal.

Home garden, nutrition garden, community garden are sources of food, and nutrients. Home gardening provides vegetables exclusively for family use. About 100 m^2 of land is required to supply a family of six. The most suitable vegetables are those producing a large yield per unit of area. Bean, cabbage, carrot, leek, lettuce, onion, parsley, pea, sweet pepper, radish, spinach, and tomato are desirable home garden crops.

Market gardening: The term 'market gardening' is usually employed to designate the growing of a general assortment of vegetables for supplying to a local market, the term "local market" meaning a market within driving distance from the point of production.

If the local market is a comparatively small town, the market garden in that vicinity does not differ materially from a properly planned home garden, except that it is larger. A general assortment of vegetables is grown, so that vegetables of some kind may be marketed at almost all seasons of the year. The growing of vegetables for local market has certain advantages over the culture of vegetables for shipment to distant markets. The grower who can market his product in his immediate locality avoids the expense of railroad transportation and a large part of the expense for packages. He is in closer touch with the market, and, except in the case of extremely perishable goods, can largely regulate the quantity of products which he will market upon a given day, and make the supply correspond quite closely with the demand at that particular time. There is, therefore, less fluctuation in prices, and more certainty of a fair profit. This is especially true of marketing in the smaller and medium sized cities.

Where the local market is a large city, the land available for gardening purposes within convenient driving distances from the market is likely to be exceedingly high priced, so that very intensive methods of culture must be practiced in order to secure large returns per acre. The intensity of the methods practiced usually varies directly with the value of the land, and depends on the size and location of the city, the distance of the particular piece of land from the heart of the city, the density and character of the population in the immediate locality, the character of the roads leading to the market, and the adaptability of the land for gardening purposes. From 2 to 4 crops are grown on the same land each season. Very heavy and frequent manuring is practiced and artificial watering is employed.

Truck-gardening: Truck-gardening or truck-growing or truck-farming, produces specific vegetables in relatively large quantities for distant markets. When vegetables are grown at so great a distance from market that road or railway or water transportation is required for reaching the market, the industry is commonly referred to as 'Truck-gardening', 'Truck-growing', 'Truck-farming', or 'Trucking'. It is usually carried on where land is low priced as compared with that on which vegetables are grown within driving distance of the large city markets. Less intensive methods of culture are practiced and a smaller assortment of vegetables is grown, but the acreage devoted to a single crop by an individual grower is usually larger in 'Truck-growing' than in 'Market gardening'. Often only 1 or 2 truck crops are grown in a given locality, and these may constitute the

"money crops" in a system of mixed farming, or in exceptional cases large areas may be devoted to a single crop by a person who gives his whole attention to that one crop. This is practiced only in regions especially adapted to the particular crop in question.

Considerations of soil and climate largely determine the general location of 'Truck-growing' areas for given crops. Of these the climate is the more important except in the case of a few crops requiring special soil conditions for their proper development. However, by no means all localities adapted to the production of certain crops have become commercial centres for those crops. The exact location of truck-growing areas within a region adapted to the production of certain crops is determined by transportation facilities and the inclinations of the inhabitants.

It is necessary that the men who wish to enter the 'Trucking business' induce a sufficient number of other men to grow the same crops to secure adequate transportation facilities.

Floating gardening: Floating vegetable garden is seen on the Dal lake in Srinagar, Kashmir valley. Most of the summer vegetables are supplied to Srinagar from these gardens. Floating gardens, labelled the '*Rad*' in the Kashmiri language are a special feature of the lake. They basically constitute of matted vegetation and earth, but are floating. A floating base is first made from the *Typha* grass which grows wild in some parts of the lake. These floats are drawn to a suitable place (generally to the north-west of the houseboats' location) and anchored. Given its rich nutrient properties, tomato, cucumber, and melons are grown with noteworthy results. All the intercultural operations etc. are done from s*hikaras* (small boats). Floating vegetable market in s*hikaras* (small boats) on Dal lake is also being done.

Much of the land in the Gaibandha district of Bangladesh is covered by water during the monsoon season, making it impossible to grow crops. Technology has been developed to allow farmers to grow food on flooded land. A floating garden is built using bamboo and water hyacinth, which is collected to construct a floating raft (6 m long and 1 m wide). This is covered with soil and cowdung, in which vegetables can be planted. A new raft needs to be built every year, but the old one can be used as fertilizer during the dry season. Summer and winter vegetables such as gourd, okra and leafy vegetables are grown. The floating gardens provide food for people even during the annual *monga* (period of food shortages) and they can also provide an alternative source of income through sale of any surplus in the market. The floating vegetable gardens are also created in ponds, canals and other water sources. A number of crops including red onion, sweet pumpkin and okra can be grown. Floating vegetable gardening is also practiced in Myanmar.

Protected gardening or Vegetable forcing: In the method known as forcing, vegetables are produced out of their normal season of outdoor production under forcing structures that admit light and induce favourable environmental conditions for plant growth. Greenhouses, nethouses, cold frames, and hotbeds, are common structures used. Hydroponics, sometimes called soilless culture, allows the grower to practice automatic watering and fertilizing, thus reducing the cost of labour. To successfully compete with other fresh market producers, greenhouse vegetable growers must either produce crops when the outdoor supply is limited or produce

quality products commanding premium prices.

World over, nearly 40 countries are involved in protected cultivation of vegetable crops. New production centres are being added constantly, mostly from developing nations. The advent of modern protected cultivation in India is a result of liberalized policy for import of seed and planting materials and economic reforms initiated in early 1990's. Though, commercial cultivation of vegetables in open field conditions is the mainstay of Indian horticulture, the protected cultivation of vegetables indeed opens up new avenues for producing quality vegetables for domestic markets and international markets. The Government of India has recognized horticulture as a major thrust area with several concessions and subsidies to promote the growth of this upcoming industry. Apart from quantum jump in yield, the protected structures are mechanical barriers to pests and vectors of viral diseases. Partial regulation of micro-climate in the greenhouse will minimize the effect of abiotic stresses. It is an eco-friendly production system to minimize the use of harmful pesticides. It has been possible to produce: (i) hybrid seeds and seedlings; (ii) to produce during off season in tropical plains and breaking the seasonality barrier in vegetables in temperate Himalayas; (iii) to produce export oriented superior quality vegetables; (iv) to combat biotic and abiotic stresses in vegetable production; and (v) to produce vegetables organically, using protected structures such as polyhouses, greenhouses and insect nethouses.

Protected cultivation of vegetables has increased the yields by many folds. Sweet pepper (capsicum) production in the tropics has increased from 40 tonne/ha in open field to 100 tonne/ha in a green-house crop of six months. Similarly in tomato grown in greenhouse during summer months, the yield has been increased to about 180 tonne/ha. The major cost however is contributed to the structure, which amounts to about 70% of the cost of production of vegetables. Therefore, to make it profitable and a sustainable farm activity, cost effective structures are to be developed, which will trigger the growth of protected cultivation in larger areas.

Vegetable farming for processing (Food preservation)

Processed vegetables include canned, frozen, dehydrated, and pickled products. The cost of production per unit area of land and per tonne is usually less for processing crops than for the same crops grown for market because raw material appearance is not a major quality factor in processing. This difference allows lower land value, less hand labour, and lower handling cost. Although many kinds of vegetables can be processed, there are marked varietal differences within each species in adaptability to a given method.

Specifications for vegetables for canning and freezing usually include small size, high quality, and uniformity. For many kinds of vegetables, a series of varieties having different dates of maturity is required to ensure a constant supply of raw material, thus enabling the factory to operate with an even flow of input over a long period. Acceptable processed vegetables should have a taste, odour, and appearance comparable with the fresh product, retain nutritive values, and have good storage stability.

Vegetable farming for seed production

This type of vegetable farming requires special skills and techniques. The crop is not ready for harvest when the edible portion of the plant reaches the stage of maturity; it must be carried through further stages of growth. Production under isolated conditions ensures the purity of seed yield. Special techniques are applied during the stage of flowering and seed development and also in harvesting and threshing of the seeds.

Organic vegetable farming

Organic farming is one alternative farming system to conventional farming practiced and has scope in appropriate regions. It is a production system in which use of synthetically compounded fertilizers, pesticides, weedicides, growth regulators, livestock feed additives are either avoided or excluded. It stands for commitment to a system of farming that strikes balance with nature using methods and materials that have a low impact on the environment. The scientific data on organic farming are scanty but there is a treasure of conventional experience with the farmers which can be used profitably to strengthen organic farming. According to Veeresh (2004), organic farming is farming without chemicals. But this seems to be incomplete because organic farming centers around a living system where the soil, plants and animals including men, are bound to the 'wheel of life' where the process of growth and the process of decay balance each other. In its most developed form, organic farming is both a philosophy and a system of agriculture, which includes all agricultural systems that promote the environmentally, socially and economically sound production of food and fibre.

Organic agriculture respects the natural capacity of plants, animals and landscape and aims to optimize quality in all aspects of agriculture and the environment, and allows the laws of nature to increase both crop yield and pest resistance (Prabhakar and Hebbar, 2004). Thus, the principles of organic vegetable farming include the following aspects:

1. Replenishing and maintaining long term fertility by providing optimal conditions for biological activity.
2. Producing viable quantities of high quality, nutritious food and feed.
3. Reducing the use of fossil fuels in agriculture and pollution that may result from farming.
4. Encouraging closed cycle farming systems that use local resources and recycled nutrients.
5. Enhancing ecological cycles within the food production system.
6. Maintaining genetic diversity of the agricultural system and its surroundings, including protection of plant and wildlife habitats.
7. Ensuring decent and nonexploitative treatment of farm workers.
8. Creating conditions for farm livestock that ensures them a life, free of undue stress, pain and suffering.
9. Maximizing the farmers' returns and satisfaction for their work.
10. Sustaining the land in a healthy condition for future generations.
11. Optimizing multiple use capacity of the land.

Organic farming of vegetables, uses manures to supply plant nutrients and

uses non chemical means for pest management. The organic fertilizations, however, affect soil organic matter content, structure, moisture retention and nutrient release. Some of these may affect plant vigour, cell size or content, thereby indirectly affecting nutritional quality and taste. Though returns from organic farming are often only 50–70% of conventional production, it is argued that organic vegetables have higher nutritional quality or better taste. ●

CHAPTER 9

Plant Nutrition

AT least 15 elements are of importance in vegetable crop production. Carbon, hydrogen and oxygen are obtained from air and water. The others are obtained from the soil and are thus potential fertilizer nutrients. Six of these are required in relatively large quantities, and are referred to as macronutrients. These are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). The other elements are used in much smaller quantities and are termed micronutrients or trace elements. These micronutrients are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) (Anon., 2011b).

Good plant development and yields, depend on an adequate supply of all these elements throughout growth. A deficiency of any one of them will affect yields detrimentally. Deficiencies of more than one element at a time are quite common. As visual symptoms of deficiencies tend to mask one another, it can be difficult to diagnose the actual problem. Specific plant symptoms which develop as a result of deficiency of a particular element may also differ markedly among different vegetable crops, and this makes identification difficult, unless a grower is experienced in this aspect. The descriptions of the more common deficiency symptoms are as under:

Macronutrients

Nitrogen: Nitrogen (N) plays an important role in the formation of protein, and is an integral part of the chlorophyll molecule. An adequate supply of N is associated with vigorous vegetative growth and a deep green colour. An oversupply of N may cause excessive, succulent growth with large, soft, thick and floppy leaves, and large, soft, poor quality fruits, or roots and tubers with poor keeping quality. Such plants often wilt easily, tend to lodge, and are more susceptible to disease and insect attack. Excess N (imbalance in the plant) can cause thin cell-walls, allowing fungi to penetrate more rapidly, whereas balanced nutrition can increase vigour of the plant. The growing period of the crop and its harvest may also be prolonged with excess N. Nitrogen is the element most likely to be deficient in vegetable production.

With the most obvious symptom being a yellowing of the older leaves first, plants show slowed growth, with the stems thin, spindly and hard, and fewer lateral shoots; leaves fade to yellowish green, even yellow, and may turn brown and die in severe cases; lower leaves are first affected; leaves are smaller and

thinner than normal; some purpling may develop under low temperature conditions; roots are not initially affected, but later become stunted and discoloured; most commonly experienced in sandy soils subject to excessive leaching, and on cold, wet soils.

Phosphorus: Phosphorus (P) is an essential constituent of many vital compounds and is present in most enzymes. An adequate supply of P tends to counter the deleterious effects of an excess of N, in that it hastens maturity, improves fruit quality, favours root growth and may increase disease resistance. Soil acidity can rapidly fix applied P into relatively unavailable forms. Phosphorus deficiency is difficult to diagnose and severe yield depressions may often occur without showing leaf-deficiency symptoms. The deficiency symptoms are:

Plant maturity and fruit setting are delayed; stems are thin and woody with shorter than normal growth; leaves tend to be smaller and darker green; undersides have a reddish purple colouration, especially on leaf veins, at first on older leaves; fibrous root development is restricted. Typically occurs in acid soils; also occurs with prolonged cold conditions, especially if soil is wet.

Potassium: The functions of potassium (K) in the plant are not fully understood. It does play an important role in the water economy of plants and reduces the tendency to wilt. It also hardens supporting tissues and thereby reduces lodging. Potassium may reduce susceptibility to disease and it improves the quality of fruits and other storage organs like swollen roots and tubers. A balanced N:K ratio is particularly important in plant nutrition, as K tends to reduce the adverse effects of excessive N. Most plants can take up large quantities of K without severe adverse effects. However, an excess of K may upset nutrient balance and thus induces deficiencies of other elements such as magnesium. Potassium is very mobile within the plant, and deficiency symptoms consequently appear first in older tissue, as K is translocated to the newer tissue where it is most needed. Deficiency of K is often shown as a marginal leaf scorch, which is progressive and irreversible, and may result in leaf death. General deficiency symptoms are as follows:

Stems slender, become woody; basal leaves first affected, greyish yellow or brown colour especially at margins, which develop scorched appearance; specks develop along veins of leaf with chlorotic areas in leaf; roots are poorly developed, discoloured. Typically occurs on excessively leached and sandy soils.

Calcium: The functions of calcium (Ca) within the plant are not clear. It is, however, considered necessary for the formation of cell-walls, and is thought to be associated with certain enzyme systems. As most soils contain sufficient Ca to satisfy plant requirements, and because of liming and the use of other fertilizers containing Ca as a secondary constituent, actual deficiencies of Ca are rare. Excess calcium does not appear to affect plant growth directly, but may affect the uptake of certain elements from the soil. The presence of adequate calcium in the soil has a suppressive effect on some seedling diseases, but may aggravate potato common scab incidence. Calcium in plant tissues can reduce bacterial soft rot. Calcium is not very mobile in plants and under certain conditions, such as drought, deficiency symptoms may occur, though there is an adequate supply of Ca in the soil. Due to this poor mobility, symptoms are usually seen in new growth or tips of leaves or fruits. The following symptoms are associated with Ca deficiency:

Stems are thick and woody, terminal buds may die. Older leaves have normal colour but new leaves may be yellowed. New growth is not turgid. Root tips die, restricting root development. Vegetables have specific symptoms such as, blossom end rot in tomato and brinjal fruit, tipburn in lettuce and cauliflower leaves, blackheart in celery, cavity spot in carrot and brown heart in endive. Calcium deficiency is expected on acid, leached soils, or soils with high potassium levels, or plants with high nitrogen levels, compared with calcium. Excess levels of aluminium (in acid soils) cause poorly developed root systems, with many adventitious roots near the soil surface.

Magnesium: Magnesium (Mg) is a constituent of chlorophyll. It assists in the production of carbohydrates, proteins and fats, and is specific to many enzyme systems. There are few reports of excess Mg. Deficiencies of Mg are common in leached, acid soils. There is usually a loss of healthy green colour between the veins of the older leaves, later spreading to younger leaves. This interveinal chlorosis may turn brown, leaves become brittle and older leaves may drop. Such deficiencies are most common on acid, leached or sandy soils which have received high potassium dressings.

Sulphur: Sulphur (S) is an essential constituent of many proteins and enzymes. Plants require about as much sulphur as phosphorus. Sulphur has little residual action in the soil as it is rapidly leached. Reports of S excess are thus rare, except possibly near certain industrial complexes where sulphur pollution occurs. Deficiency symptoms are as follows:

Stems are elongated, spindly and woody. Lower leaves are thick and firm, developing chlorosis, which may be confused with nitrogen deficiency. Root system is extensively developed, but spindly roots. Sulphur deficiency could develop in sandy soils, if no sulphur containing fertilizers are applied.

Micro-nutrients (Trace elements)

Boron: Crop requirements for boron (B) vary quite markedly, with deficiency symptoms probably most common on cabbage, cauliflower and beet root. General deficiency symptoms are:

New buds, leaves and petioles are light in colour and may be distorted. There may be rosetting at shoot terminals, due to multiple bud development. Stems are shortened and internodes short; with extreme deficiency buds die. Cauliflower may show hollow stem, celery develops cracked stem. Root growth is retarded; discoloured corky areas form in root crops, e.g. internal browning in turnip and brown heart of beetroot. Deficiency may occur in any soil, but it is more common on light sandy soils, or soils which have recently been heavily limed. Some crops have a higher boron requirement than others. Excessive boron may cause yellowing and necrosis of the margins of primary leaves.

Molybdenum: Molybdenum (Mo) is required in minute quantities for assimilating nitrates, as well as for fixing atmospheric N in the root nodules of legumes. Excess Mo in plants can be harmful to animals that eat them as it can cause sterility, amongst other things. Deficiencies of Mo are quite common in several vegetable crops. This is partially due to a reduced uptake of Mo on acid soils; adequate liming will sometimes solve the problem. Cauliflower is sometimes

used as an indicator plant to show Mo deficiency because of its great susceptibility. Cabbage and cucurbits are also fairly easily affected. General symptoms are:

Older leaves have inter-veinal chlorosis, new leaves may be green but become mottled in developing. Leaves are distorted at edges, later are narrow and very distorted, e.g. whiptail in cauliflower. Heads of cauliflower have small, open curds.

Zinc: Zinc (Zn) is a very important trace element with deficiency symptoms being widespread in many areas. Vegetable crops commonly affected include green beans, and sweet-corn. The deficiency symptoms are often found in scattered patches in a land, with apparently healthy plants growing close to others showing acute deficiencies. Symptoms are: Inter-veinal chlorosis in new leaves and later the whole leaf becomes chlorotic. In some cases there may be necrosis of leaf tissue. New leaves are small. Occurs in cold wet soils or with excess phosphate fertilization or liming to pH values above 5.5 in KCl.

Manganese: Manganese (Mn) becomes more soluble in acid soils and is thus more likely to cause toxicity than deficiencies. Toxicity may also be induced by waterlogging. Deficiencies are generally found in naturally alkaline or calcareous areas, which tend to occur in drier climates, or elsewhere soils have been overlimed and have a pH value in KCl of over 5.5. Inter-veinal chlorosis starts in new leaves, with older leaves affected later. Veins remain green. Chlorotic areas may fade to light brown and then die. Beetroot leaves become redder and onion leaves show narrow chlorotic striping. Toxic levels of manganese in acid soils can be corrected by liming. Symptoms of Mn toxicity vary among vegetable crops. There is slow growth and necrotic spots on young plants. Small black spots develop on stems and on the underside of mature leaves. Veinal chlorosis may be seen on leaves and their inter-veinal areas may have some yellowing.

Iron: Iron (Fe) deficiency symptoms are similar to those of Mn. There is also inter-veinal chlorosis, a distinct light yellow, which may develop to a more uniform yellow, almost white, in the leaf. It also commences in the young leaves. Usually there is no necrosis (dieback). Iron deficiency is common in calcareous, alkaline or overlimed soils.

Copper: Copper (Cu) deficiencies throughout the country are rare. It could be expected in soils which are very high in organic matter. Plant growth is retarded, and leaves may appear elongated. Leaves are softer than normal and may show a light chlorosis.

Sodium and chlorine: These 2 elements are not a consideration in plant nutrition, except for their role as constituents in salt toxicity in plants. Where saline water is used for irrigation, salts accumulate in the root zone. Salt uptake may result in elevated tissue levels of sodium (Na) and chlorine (Cl). Tipburn and stunting symptoms of salt toxicity are actually the manifestation of induced physiological drought in vascular tissues.

Fertilizers

Fertilizers are primarily valued for their ability to supply nutrients. Plants use these nutrients to make components for plant growth such as proteins and carbohydrates. The main chemicals that must be supplied to plants are called primary nutrients. Those required in the greatest amounts are nitrogen (N),

phosphorus (P), and potassium (K). Plants also require the secondary nutrients, calcium, magnesium, and sulphur, plus very small amounts of the micronutrients boron, copper, chlorine, iron, manganese, molybdenum, and zinc. These latter, plus a few others, are referred to as trace elements.

Inorganic or "chemical" fertilizers are typically less expensive (per kg of nutrient) and more readily available for plant growth than organic fertilizers. However, the organic manures have the advantage of supplying other nutrients in addition to N-P-K (releasing nutrients slowly over the growing season). Some fertilizers can be absorbed immediately upon application. These are known as quick release or highly soluble fertilizers. They are useful when rapid results are required. They come in liquid or powder form and are applied to root zones or sprayed directly on foliage.

Nitrogenous fertilizers: According to the manner in which their nitrogen is combined with other elements, the nitrogenous fertilisers are divided into four groups; nitrate, ammonia, and ammonium salts, chemical compounds containing nitrogen in the amide form, and plant and animal by-products. Various nitrogenous fertilizers are furnished in Table 7.

Table 7. Nitrogenous fertilizers with their N content (%)

Fertilizers	Formula	% N
Sodium nitrate	$(NaNO_3)$	16
Calcium nitrate	$Ca(NO_3)_2$	15.5
Ammonium Sulphate	$(NH_4)_2SO_4$	20.6
Ammonium Chloride	NH_4CL	25
Ammonium phosphate	$NH_4 (H_2PO_4)$	20
Anhydrous ammonia	NH_3	82
Ammonia Solution	NH_3 in water	20 to 25
Ammonium nitrate	NH_4NO_3	33 to 34
Calcium Ammonium Nitrate (CAN)	$Ca(No_3)_2NH_4NO_3$	25
Ammonium Sulphate Nitrate	(ASN) -$(NH_4)_2SO_4NH_4NO_3$	26
Urea	$CO(NH_2)_2$	46
Calcium cyanamide	$CaCN_2$	21

Phosphatic fertilizers: The nutrient phosphorus present in phosphate fertilizers are usually expressed in terms of phosphoric anhydride or simply as phosphorus pentaoxide, P_2O_5. Various phosphatic fertilizers are furnished in Table 8.

Table 8. Phosphatic fertilizers with their P_2O_5 content (%)

Fertilizers	Formula	% P_2O_5
Single Superphosphate	$(CaH_2PO_4)16$	18
Double superphosphate	$CaH_4(PO_4)_2$	32
Triple superphosphate	$Ca(H_2PO_4)_2$	46 to 48
Ammonium phosphate		20
Dicalcium phosphate	$CaHPO_4$	14 soluble
Basic slag	$(CaO)_5P_2O_5 \cdot SiO_2$ 17	20 extract soluble
Calcium metaphosphate	$Ca(PO_3)_2$	60 to 64 extract soluble
Rock Phosphate	$Ca_3(PO_4)2CaF_2$	20 to 30 extract soluble
Bone meal	$(Ca(PO_4)_2)_3 CaF_2$	21 to 25 extract soluble

Table 9. Potassic fertilizers with their K_2O content (%)

Fertilizer	Formula	% K_2O
Potassium chloride or muriate of potash	(KCl)	48 to 62
Potassium sulphate or sulphate of potash	(K_2SO_4)	48 to 52
Potassium Magnesium sulphate	($K_2SO_4 . 2MgSO_4$)	22
Potassium Schoenite	($K_2SO_4 . MgSO_4 . 6H_2O$)	22 to 24

Potassic fertilizers: The potassium content of potassic fertilizers is usually expressed as potassium oxide. K_2O, referred to as potash. Various potassic fertilizers are furnished in Table 9.

Most retail fertilizers are labeled with a three number analysis corresponding to N, P, and K. It tells what percentage of the net weight is actually composed of these three nutrients. A fertilizer containing all three nutrients is a balanced fertilizer. Some common N-P-K analyses of inorganic, granular fertilizers are 10-6-4, 5-10-5, and 10-10-10. A 50 kg bag of 10-6-4 fertilizer will contain 5 kg of nitrogen (N), 3 kg of phosphate (P_2O_5), and 2 kg of potash (K_2O). (Phosphate and potash are merely the available forms of phosphorus and potassium respectively). •

CHAPTER 10

Raising of Vegetable Crops in the Field

VEGETABLES are propagated either by vegetative methods or by means of seed, depending on the crop. Examples of those usually propagated vegetatively are potato ('seed' tubers), sweet potato generally vine cuttings), garlic (the bulbs are divided into cloves, with the larger ones being used for planting), Jerusalem artichoke (the edible tubers), globe artichoke and rhubarb (division of existing plants), and so on. However, most vegetables are produced from true seed. Most plants can be successfully transplanted at a very young age. However, this period is short for certain crops, such as various beans, carrot, cucurbits, parsnip, peas, sweet-corn and so on, that the disadvantages of transplants usually far outweigh the advantages, and transplanting is seldom a practical consideration. Such crops are thus sown directly into the production field in their paramount positions. Even those crops which may be successfully transplanted are, at times, seeded directly into the production field (Anon., 2011b).

Seed quality

It is important to use quality seed that is true to type, has a high germination percentage, has a high vigour, has no dormancy, is free of foreign matter and has no disease contamination. Two types of seed are available: open pollinated and hybrid seed. Hybrid seed is more expensive, but an improved crop uniformity can be expected due to the selection of favourable characteristics. Hybrid seed is a combination of two or more genetically distinct parental inbred lines. Open pollinated seed is low-priced and does require the same management practices as needed to produce hybrid seed.

Direct seeding

The land preparation for direct seeding should be at least as good if not better than that used for transplants. It should be close to that used for open seedbeds, particularly when small-seeded crops are to be sown. The field should have a good tilth without any large clods, should be firm and as level as possible. An uneven surface leads to an uneven depth of planting, resulting in less uniform emergence, growth and maturity. Obviously any basal fertilizer dressings should be worked in before sowing.

Small seeds, such as carrot, cole crops, lettuce and tomato, are generally drilled to a depth of 1–1.5 cm, occasionally up to 2–2.5 cm. Shallower sowing is seldom

used because the surface layers of the soil dry out too rapidly, and it is difficult to keep the seed moist enough for successful germination and emergence. Sowing will generally be deeper on sandy soils than on heavy soils.

Planting depth for larger seeds, such as bean, pea or sweet-corn, may also be shallow, but it is usually more common for them to be drilled one and a half-times as deep as small seeds. Firm down the soil down over the seed after planting to ensure good seed-to-soil contact. It is usually better to plant into moist soil, which had been wetted to the rooting depth of the crop a few days previously, and then to give a light irrigation soon after planting to settle the soil around the seed. Make sure that the soil around the seeds remains moist by frequent light irrigations until the plants emerge remember that the top layers of soil can dry out rapidly.

Transplanting

Apart from the crops discussed above, there is another group which transplant comparatively easily and successfully, even at a more advanced age. These include crops such as brinjal, broccoli, Brussels sprouts, cabbage, cauliflower, celery, chilli, leek, lettuce, onion, sweet pepper and tomato. It is common practice to raise them in seedbeds or seedtrays, for later establishment in their permanent positions in the field. The main advantages of transplanting revolve around the fact that the area used for growing transplants is small in comparison with the size of the production fields. This results in: better utilization of available ground, because the larger fields may be used for crop production while the seedlings are being produced. Better germination, seedling growth, and plant survival, resulting in lower usage of seed, because the small seedbed can be cared for better than the large fields. Better, quicker and low-priced control of pests, diseases and weeds on a small area. Better control of irrigation, with a saving in water usage, and more frequent watering, ensuring consistent seedling growth. Easier and low-priced protection of seedlings against wind, hail, rain, heat and, cold. Earlier cropping is possible in areas with cold winters by producing seedlings under cover, or in a warmer area, and transplanting when outside conditions become favourable for growth. More uniform plant spacing, as well as replacement of ‘missing’ plants when established in the production field.

The disadvantages include: The unavailability or high cost of labour needed for transplanting. Transplanting losses may, under favourable conditions, result in a poor stand and low yields. The time taken from sowing to harvesting is normally extended because plant growth may be set back to some extent by transplanting. Transplants are usually raised in seedtrays or in open seedbeds. Seedtrays are normally used by speacialized nursery-men producing plants for sale to growers. Although a few vegetable growers do make use of this system for the production of their seedlings, the majority of producers who grow their own transplants, use open seedbeds for this purpose. The quality, including age, of transplants plays a large role in determining the potential yield of the resultant crop. Seedling production should, therefore, receive special attention from each grower, because poorly grown seedlings can never produce the yields, nor the quality, that can be achieved with young, strong, healthy transplants.

Raising of seedlings

In commercial practice there are 2 main methods of producing transplants. The first is to produce the seedlings in seedling trays, usually using composted coir pith/cocopeat as a growing medium, and usually under cover, and the other is to grow the seedlings in soil in seed beds situated in the open.

Seedling trays: Most transplants are produced in seedling trays and mostly by specialized commercial nursery-men. The most commonly used structures in which the seedlings are produced are shade houses, which make use of 40 mesh nylon shadenets. Different colours, as well as different percentage shade, are available. These houses should not be shaded or exposed to high winds. Should the seedlings be grown in trays placed directly on the ground, or any other solid surface, their roots will tend to grow out of the drainage holes at the bottom of the growing cavities (or cells). At transplanting this would cause difficulty in removing the seedlings, would damage the roots, causing a greater transplanting shock and plant setback and would negate most of the advantages of raising plants in such containers. If the trays were to be raised about 60 cm above ground, with the drainage holes exposed to the air, roots do not grow out of them and would remain within the cell cavity, with much better transplanting results.

The trays used for large-scale production are usually about 67 cm long, 34 cm wide and 5–6 cm deep. The number of cavities per tray varies. The fewer the cavities per tray, the larger the cells are, and the longer the seedling can be kept before becoming root bound. The cost of producing each seedling is appreciably higher, as fewer seedlings are produced over time per unit area, and more growing medium is used per plant in large cavities. Because of this cost factor, commercial nurseries favour the use of trays with many small cavities, say a count of 300 per tray, whereas growers often prefer those with larger cavities, say 200 cells, or even 128 cells for certain crops such as tomato. The trays are available in plastic or polystyrene. Plastic trays are heavier, making movement in the nursery more onerous, but they are less prone to breakage. Ploystyrene trays are lighter but not as durable. The higher price of plastic trays is recovered by their longer life span. The production fields must be prepared for the plantlets before they are received from the nursery.

Well-decomposed coir pith/cocopeat that is weed-free is recommended for seedling trays. Seed is normally planted mechanically into the tray cavities. The trays are then lightly irrigated and placed in germination rooms with high humidity and moderate temperature. About three days later the trays are removed and placed in the nursery where they are irrigated, often several times a day during hot weather. Nutrients are added to this irrigation water. It is essential that the runoff water is drained from the nursery, as pooled water is ultimately detrimental to the health of the growing plants. To prevent disease, the trays are sterilised before planting, either by means of steam or chemical means. It is essential with seedling production to maintain good sanitation in the nursery.

Open seed bed: The site for a seed bed must be carefully selected. It should be easily accessible, because the seedbeds should be inspected and attended to daily, in order to make management decisions on irrigation, pest and disease control. Avoid using soils subject to crusting. Preferably, select lighter soil-types, such as

sandy loam to loam soils. These soils warm up quickly, generally drain well, are easier to cultivate, and most seedlings will emerge more easily, and grow better. Frequent light irrigations are required for optimum germination and growth, making a good water source essential. The site should be protected from cold and wind. However, be careful of windbreaks, or other trees possibly shading the seedlings or competing for root space. A good air circulation is advisable to reduce disease incidence. Virgin land would be preferable, followed by a three-year rotation.

The soil needs to be well prepared, and in good tilth. As most transplanted vegetables have relatively small seeds, the soil surface should be fine, but not pulverized. The soil should be well manured/fertilized. The beds are usually made about 1.0 m wide, and of any convenient length. They should be level across their width, with no high spots (too dry) or low spots (too wet). The beds are usually raised about 15 cm above the access pathways between them, to facilitate drainage.

The seed is sown thinly, usually in shallow furrows drawn 10–15 cm apart, and covered to a depth of 1.0–2.0 cm for most vegetables. As a general rule, sow about 100–150 seeds/m plant row. The seed rate for any crop will obviously vary, depending on the number of seeds per g the particular seed lot, its germination ability, the growing conditions to which it is subjected, and the plant population desired on the land. Common seed rate for most cole crops (cabbage family) is 300–400 g/ha, for capsicums (chillies and sweet peppers) is 250–350 g/ha, for tomatoes is 250 g/ha, for brinjal and lettuce is 500 g/ha, and for onions is 3.0–5.0 kg/ha. Many growers customarily sow 10–15% more seed than is considered necessary, to ensure that there are sufficient plants, even after fairly stringent selection.

After sowing, frequent (daily or even twice daily during hot, dry weather), light irrigations are necessary to prevent the drying out of the topsoil in which the seed is planted. After emergence, gradually increase the interval between irrigations to about seven days as the plants become stronger. Ensure that the seedbed does not become too wet, because such conditions favour the development of many diseases, especially damping-off and some foliar diseases. Reduce watering over the last 7–10 days before transplanting, in order to harden the plants, but do not allow the seedlings to wilt severely. If the plants have been produced under shadenet or other shelter, the cover should be gradually removed to acclimatize the plants to the outside field conditions. Give the beds a good soaking a day or two before transplanting, to restore a good water regime in the seedlings, and to facilitate lifting of the plants with minimal root damage. During growth in the seedbeds, attention to weed control, as well as the control of pests or diseases, should receive priority.

Minimizing diseases in vegetable transplants

Shade house environment: Production houses could be located in areas where vegetables are not produced, to prevent the presence of disease-causing agents. Weeds around the shadenet house should be removed, and volunteer or redundant seedlings removed and destroyed.

Media and water: All growing media and irrigation water should be pathogen

free. In some instances, water pipes should have filters fitted to exclude propagules of known pathogens.

Planting material: Only certified seed or plant plugs should be used. The grower must not accept seeds or seedlings of unknown quality for use in transplant production.

Cultural practices: Attention must be given to practices such as fertilization, irrigation and temperature. Free moisture from sprinklers or condensation on plants for prolonged periods should be avoided. Strict sanitation should be followed as well as removing weeds from underneath the benches.

Transplanting in the field

Short, sturdy, slightly hardened seedlings, with a well developed root system, transplant and perform better than soft, lanky, etiolated seedlings. The latter are encouraged by sowing too densely (seedbed area is too small), over use of nitrogen fertilizers, and over watering. Younger plants of the desired size perform better than older ones. Under warm growing conditions, most of these crops will reach the transplanting stage within 4–6 weeks, but this period may be doubled under colder conditions. Traditional transplant size is when the plant is at the 5–6 true leaf stage.

Only those seedlings which have reached the desired size are used for the first planting out. Those developing more slowly may be transplanted slightly later, when they are more developed, but are less likely to perform as well. Hardening, which is the process of adapting seedlings to field conditions should take place 7–14 days prior to transplanting. Hardening will increase the transplanting success rate, to do this withhold moisture or reduce/increase the temperature to which the plant's are exposed to. Overcrowding of seedlings is often the main cause of variation in growth and plant size. Lift the plants carefully, with as little root damage as possible, and cover them with moist sacks until transplanted. Transplanting success depends on how rapidly a plant is able to regenerate those areas of the root system that were damaged by removal from trays/seedbed and from transplanting. Lift only sufficient plants to keep the planters continually busy. Any weak, diseased or abnormal plants should be discarded. Transplanting should be done as early in the morning or as late in the afternoon as possible. This is when the humidity is at it's highest, reducing dessication, as well as it being the coolest time of the day. Plant into moist soil, if possible. Set the plants slightly deeper than they were in the seedbeds, firm the soil around the roots, and irrigate again as soon as possible after transplanting. Special attention should be paid to further irrigation, and replacing any dead or weak plants, until the plants have recovered from any transplanting shock.

Plant population and spacing

Plant population refers to the number of plants per unit area of land. *Example*: 40,000 plants/ha (e.g. cabbage) or 100 plants/m^2 (e.g. carrot).

Plant spacing, on the other hand, refers to the arrangement of plants on the area planted.

Example: Widely varying plant spacings such as 100 cm × 1 cm, 50 cm × 2 cm

and 10 cm × 10 cm, all give a plant population of 100 plants/m^2.

The size and shape of the root system of most plants are generally in proportion to the size and shape of their top growth. Thus we find that plants like lettuce, cabbage and cauliflower, with a fairly compact 'rounded' top growth, generally have compact, rounded rootsystems, but lettuce, being smaller, should be planted closer together than cabbage for optimum yields.

Small growing (short), more upright growing crops, like onion or carrot, have relatively shallow roots, with limited lateral (sideways) spread.

Rambling crops, such as pumpkin, squash, on the other hand, tend to have rather sparse, but spreading, root systems, similar in size and spread to that of the top growth. Squash, being less vigorous than the others mentioned, requires a closer spacing (a higher plant population) for optimum yields.

In cases where climate, soil and nutrient status are all favourable for growth, plants will grow larger and have better developed root systems and this could require a wider than normal spacing. A lower plant population is also justified when conditions such as limited soil moisture are a likely limitation to the crop.

With an understanding of a plant's growth behaviour, and the conditions under which it is to be grown, it is possible to make a good estimate of a suitable plant spacing for most vegetable crops. •

CHAPTER 11

Principles of Vegetable Farming

PRINCIPLES of vegetable farming are as discussed here.

Weather and climate

Each vegetable crop has certain climatic requirements. Unfavourable weather and climatic conditions produce a stress. Components of weather and climate include the temperature, light/daylight, moisture/rainfall, and wind and topography of the site and soil conditions of a specific region. Climatic factors strongly affect all stages and processes of plant growth. The crop growth and development and finally harvest of the crop are influenced by climatic factors such as temperature, light and humidity and soil factors such as moisture, aeration, *p*H and nutritional status.

Temperature

Temperature influences all physiological activities by controlling phytosynthesis, respiration, enzymic activity, organic matter decomposition, microbial growth and development, flowering, pollen viability, fruit-set, hormonal balance, rate of maturation, rate of senescence, quality, yield, shelf-life, harvest duration, vernalization of biennials, seed germination, root development, water and nutrient absorption, pests and disease occurrence.Extremes of temperatures may also cause crop damage, e.g., frost damage at 0°C; chilling injury at 0–2°C or lower, but above freezing point.

Temperature requirements are based on the minimum, optimum, and maximum temperatures during both day and night throughout the period of plant growth. Requirements vary according to the type and variety of the specific crop. Based on their optimum temperature ranges, vegetables may be classed as cool-season or warm-season types. Cool-season vegetables thrive in areas where the mean daily temperature does not rise above 21°C. This group includes the artichoke, beet, broccoli, brussels sprouts, cabbage, carrot, cauliflower, celery, garlic, leek, lettuce, onion, parsley, pea, potato, radish, spinach, and turnip. Warm-season vegetables, requiring mean daily temperature of 21°C or above, are intolerant of frost. These include the bean, cucumber, eggplant, lima bean, okra, muskmelon, pepper, squash, sweet-corn (maize), sweet potato, tomato and watermelon.

Premature seeding, or bolting, is an undesirable condition that is sometimes seen in fields of cabbage, celery, lettuce, onion, and spinach. The condition occurs when the plant goes into the seeding stage before the edible portion reaches a

marketable size. Bolting is attributed to either extremely low or high temperature conditions in combination with inherited traits. Specific vegetable varieties may exhibit significant differences in their tendency to bolt.

Young cabbage or onion plants of relatively large size may bolt upon exposure to low temperatures near 10°–13°C. At high temperatures of 21°–27°C lettuce plants do not form heads and will show premature seeding. The fruit sets of tomatoes are adversely affected by relatively low and relatively high temperatures. Tomato breeders, however, have developed several new varieties, some setting fruits at a temperature as low as 4°C and others at a temperature as high as 32°C.

Temperature is considered as the most important factor which influences general survival, seed germination, development of economic parts, flowering, pollination, fruit-set, quality of produce and seed production of the crop. It means temperature plays very important role starting from sowing of seeds in the field to the final harvest of vegetable crops. All the chemical and physiological processes in plant are governed by temperature and ultimately affect the growth and development of the crop. The growth rate increases with the increase in temperature within the range of 12–30°C, and it declines as temperature increases above 30°C. It means that the physiological processes in plant require a particular range of temperature to function properly. Most of them function properly within the temperature range of 20–30°C, called optimum temperature. If temperature is below the optimum, chemical reactions in plant slow down and utilization of photosynthates reduces. On the other hand, if the temperature rises above the optimum range, excessive loss of photosynthates occurs due to high respiration rate. There is destruction of enzyme system responsible for physiological processes when temperature is higher than 45°C. There is complex relationship between temperature, light and plant growth and development of vegetable crops depending upon their response. For example, vegetable crop requiring low temperature like spinach, will flower if the temperature is high and day length is long. In vegetable crops requiring warm temperature like tomato, fruit set is prevented when the temperature is too low. Besides, adverse temperatures also cause stunted growth and poor quality of produce. For example, high temperature causes bitterness in lettuce. Thus, vegetable crops differ in their temperature requirement. Some vegetables thrive best under cool temperatures and others require relatively high temperatures. On the basis of temperature requirement vegetable crops can be grouped into two groups—cool or winter vegetable crops and warm or summer vegetable crops.

Cool or winter season vegetables prefer mean growing temperature between 10° and 18°C for their growth but grow best at temperature ranging from 15–18°C. Most of them produce edible parts; leaf, stem and roots. Some winter vegetables like cabbage, lettuce and garden beet can tolerate very low temperature of 5°C. Some temperate carrot and cabbage require chilling temperature for bolting (flowering), whereas, in some vegetables low temperature at maturity causes injury.

Warm-season vegetables require mean growing temperature within a range of 18–30°C for their growth and development but grow best at temperature between 18–27°C. Most of them produce edible portion; fruits. Most of the summer vegetables suffer when temperature goes below 15°C. They are susceptible to frost.

All the stages of plant growth are affected by temperature, as detailed below:

Seed germination: Seeds of winter vegetables do not germinate when they are sown during summer. During winter, seeds of summer vegetables do not germinate. The temperature requirement for seed germination ranges from 15 to 30°C. The optimum temperature required for seed germination of most of the crops is 24–30°C. Temperature beyond 30ºC show detrimental effects on the seed germination. Temperature requirement for seed germination of different vegetable crops is given in Table 10 (Nath *et al.* 2002).

Table 10. Temperature requirement for seed germination in different vegetable crops

Crop	Soil temperature (°C)			
	Minimum	Optimum range	Optimum	Maximum
Tomato	10.0	15.5–25.0	25.0	30.0
Brinjal	15.5	24.0–32.0	28.0	35.0
Chilli	15.5	18.0–35.0	29.0	35.0
Potato	10.0	15.0–25.0	25.0	30.0
Cabbage	4.4	10.0–30.0	20.0	37.8
Cauliflower	4.4	10.0–30.0	25.0	37.8
Radish	4.4	7.0–32.0	28.0	35.0
Carrot	4.4	7.0–26.0	24.0	35.0
Turnip	4.4	15.0–35.0	29.0	40.0
Beet	4.4	10.0–29.0	26.0	35.0
Parsnip	1.6	10.0–21.0	18.0	29.4
Asparagus	10.0	25.0–30.0	30.0	35.0
Muskmelon	15.5	24.0–35.0	30.0	37.8
Cucumber	15.5	15.5–35.0	30.0	40.5
Watermelon	15.5	21.0–35.0	30.0	40.5
Summer squash	15.5	21.0–35.0	30.0	37.8
Pumpkin	15.5	21.0–32.0	30.0	37.8
Bitter-gourd	15.5	20.0–35.0	32.0	37.8
Ridge-gourd	15.5	21.0–35.0	30.0	40.5
Sweet-corn	10.0	15.5–35.0	35.0	40.5
Okra	17.0	21.0–35.0	29.0	40.5
Pea	4.4	4.4–24.0	22.0	29.4
French bean	15.5	15.5–29.0	26.0	35.0
Lima bean	15.5	18.0–29.0	26.0	29.0
Cowpea	15.5	15.5–29.0	28.5	40.5
Hyacinth bean	15.5	15.5–29.0	28.0	35.0
Cluster bean	15.5	15.5–35.0	29.0	35.0
Palak	10.0	15.0–30.0	25.0	35.0
Amaranthus	10.0	15.0–35.0	32.0	35.0
Spinach	1.6	7.2–23.9	21.1	29.4
Celery	4.4	15.5–21.1	21.1	29.4
Swiss chard	4.4	10.0–29.4	29.4	35.0
Lettuce	1.6	4.4–26.6	23.9	29.4
Parsley	4.4	10.0–29.4	23.9	32.2
Onion	1.6	10.0–35.0	23.9	35.0
Drumstick	15.0	20.0–35.0	29.0	40.0

Development of edible parts: The productivity of a crop depends on the development of the edible parts of the vegetable crop plant, which is controlled by temperature at a critical stage in plant growth and development. 20–24°C is favourable for sprouting and initial growth; 18–20°C is favourable for subsequent growth and tuberization in potato and above 30°C is detrimental for tuberization. 20–22°C is favourable for bulb formation in onion. A temperature of 15–21°C is favourable for root development in carrot, 20–25°C is favourable for curd formation in early varieties and around 10°C is favourable for curd formation in late varieties of cauliflower.

Flowering, fruiting and seed production: Flowering, fruiting and seed setting are affected by temperature. Most of the vegetable crops flower during periods of moderate to warm weather. Under favourable temperatures, the normal edible parts of the vegetables, viz. lettuce, cauliflower, spinach, Chinese cabbage (annuals), cabbage, carrot, onion (biennials) are harvested for consumption prior to flowering (bolting) before reaching marketable stage. When plants are subjected to temperature below the optimum, pre-mature flowering, known as bolting takes place. Bolting is a problem that occurs frequently in winter vegetables which cause yield losses. Some crops require low temperature for flower induction known as vernalization (More, 1994). It is also known as chilling requirement of the crop. Chilling period should have average temperature below 7°C for 2–8 weeks. The night temperature plays a very important role in fruit setting in solanaceous vegetables like tomato. Generally, average monthly night temperature of 21–23°C is optimum for fruit setting in tomato.

Quality of produce: The quality of vegetable produce is also affected by temperature. For example, at low temperatures sugars tend to accumulate, there is less fibre and flavour development in vegetable crops, whereas warm temperature is favourable for sweetness and flavour development in musk melon and water melon. The intensity of colour development in tomato depends on the presence of red and yellow pigments which are influenced by temperature: 10°C is favourable for yellow colour development, below 30°C for red colour development in tomato. Optimum temperature for red and yellow colour development is 10–30°C.

In carrot best colour development takes place at temperature range of 15–22°C. Higher temperatures cause stocky and spindle-shaped roots. Generally, creamy-white and compact curds of cauliflower are desirable. Fluctuation in temperature influences the quality of curds. Buttoning in early cauliflower is due to cool weather.

Bolting, buttoning and blindness are due to low temperature (–1 to –2°C) when plants are exposed at 6–7 leaf stage. Riceyness is due to high temperature at maturity of curds. Loose and leafy curds are due to high temperature at curd initiation.

Favourable temperature range and days to maturity of various vegetable crops are given in Table 11 (Nath *et al.* 2002). Temperature requirements for successful cultivation of different vegetables are given in Table 12.

Effects of high temperature on vegetable crops are, sunscald and discolouration of fruits in tomato; flower dropping in beans, capsicum, tomato; quick growth of okra fruits; loss of sugar in peas due to high rate of respiration; bolting and

Table 11. Favourable temperature range and days to maturity for various vegetable crops

Crop	Maturity (days)	Temperature requirement (°C)		
		Minimum	Optimum	Maximum
		Rabi		
Radish*	30–60	4–5	10–18	21
Greeen onion*	40–45	4–5	10–18	21
Spinach beet*	40–90	4–5	10–18	21
Turnip*	50–70	4–5	10–18	21
Peas *	60–70	4–5	10–18	21
Beet*	60–70	4–5	10–18	21
Cauliflower	60–80	10	16–18	21
Lettuce (head)	70–85	10	16–18	21
Asparagus	Perennial	10	16–18	21
Knol-khol	60–75[1]	10	16–18	21
Cabbage	70–100[1]	10	16–18	21
Carrot	40–60	10	16–18	21
Onion	90–110	10	16–18	21
Garlic	90–110	10	16–18	21
French bean	60–90	10	16–21	24
	Kharif and rainy season			
TomatoCucumber	60–90[1]60–70	1616	18–2418–24	3030
French bean	55–90	16	18–24	30
Pepper	65–80[1]	18.3	24–27	35
Brinjal	80–110[1]	18.3	24–27	35
Okra	60–110	18.3	24–27	35
Chillies	80–100[1]	18.3	24–27	35
Sponge gourd	60–90	18.3	24–27	35
Ridge gourd	60–90	18.3	24–27	35
Pumpkin	75–180	18.3	24–27	35
Cowpea	50–60	18.3	24–27	35
Cluster bean	50–70	18.3	24–27	35
Watermelon	75–100	18.3	27–30	38
Muskmelon	70–90	18.3	27–30	38
Long melon	55–90	18.3	27–30	38
Snap melon	70–90	18.3	27–30	38
Round melon	60–90	18.3	27–30	38
Bitter-gourd	55–110	18.3	24–27	34
Bottle-gourd	60–100	18.3	27–30	38
Snake-gourd	60–100	18.3	27–30	38
Ash-gourd	75–120	18.3	27–30	38
Pointed-gourd	Perrenial	18.3	27–30	38
Squash	60–80	18.3	27–30	38
Amaranth	25–50	18.3	27–30	38

*will stand frost

[1]From time of transplanting, rest of the days are from sowing to harvest.

[2]Below the minimum and maximum, the growth and reproduction will be checked.

buttoning in cauliflower; yellowing in cabbage; small roots development in carrot; less tuberization in potato; wilting and loss of flavour in leafy vegetables; maturity stage in peas and corn is passed quickly resulting in starchiness and toughness.

Effects of low temperature on vegetable crops, plant death due to freezing of cell-sap; damage to roots, buds and stem; rotting in winter cauliflower; exposure of celery, beet, cabbage and carrot (biennial vegetable) to a temperature of 10°C

Table 12. Temperature requirement for successful cultivation of different vegetable crops

Group	Monthly mean temperature (°C) [day and night]			Vegetable crops
	Minimum	Maximum	Optimum	
Hot	18.0	35.0	25.0–27.0	Okra, watermelon, muskmelon, chilli, sweet potato, yam, cassava, amaranth, winged bean, cluster bean
Warm	10.0	35.0	20.0–25.0	Tomato, sweet potato, brinjal, lima bean, French bean, hyacinth bean, cowpea, sweet corn, palak, New Zealand spinach, cucumber, pumpkin, pointed-gourd, ridge gound, snake-gourd, drumstick, Indian spinach, portulaca, elephant foot yam
Cool-hot	5.0	30.0	20.0–25.0	Onion, leek, garlic, shallot, chicory, chives salsify, pak-choi, taro, globe artichoke, Indian cauliflower.
Cool-warm	5.0	25.0	8.0–25.0	Pea, broad bean, cauliflower, cabbage, beet, chinese cabbage, broccoli, kale, brussels sprouts, knol-khol, turnip, radish, carrot, rutabaga, horse radish, parsnip, potato, dil, parsley, fennel, Swiss chard, spinach, asparagus, garden cress, mustard, celeriac.

or below, for 5–6 weeks will cause them to produce seed stalk in the first season and thus head formation does not take place; poor colour development in carrot.

Light (daylight)

Photosynthesis uses light. Light intensity and duration are important for crop growth and development. Low light causes plants to be spindly, small leaves, bud blades, poor pollination and poor fruit quality. Plants differ in light requirements as under:

(i) Light affects pollen viability and fruit set.
(ii) Certain seeds require light to break dormancy. e.g., lettuce.
(iii) Some vegetable crops are sensitive to photoperiod.
(iv) Short-day plants flower rapidly when the days get shorter.

Light intensity and duration are important for crop growth and development as under:

(i) Photosynthesis uses light.
(ii) Low light causes plants to be long and thin (spindly), small leaves, bud blades, poor pollination and poor fruit quality.
(iii) Photosynthesis is stopped at high light intensity depending on species.
(iv) Plants differ in light requirements.
(v) Certain seeds require light to break dormancy.
(vi) Some plants are sensitive to photoperiod or day-length.

(vii) Short-day plants flower rapidly when the days get shorter.
(viii) Long-day plants flower when days are longer.
(ix) Short-day hasten tuber formation in potato, root enlargement in sweet potato.
(x) Long-day and high temperatures keep plants in staminate (phase) in cucurbits.

Light is the source of energy for plants. The response of plants to light is dependent on light intensity, quality, and daily duration, or photoperiod (photoperiodism). The seasonal variation in day length affects the growth and flowering of certain vegetable crops. Continuation of vegetative growth, rather than early flower formation, is desirable in such crops as spinach and lettuce. When planted very late in the spring, these crops tend to produce flowers and seeds during the long-day of summer before they attain sufficient vegetative growth to produce maximum yields. The minimum photoperiod required for formation of bulbs in garlic and onion plants differs among varieties, and local day-length is a determining factor in the selection of varieties.

Light plays very vital role in plant-life because it is a form of radiant energy. Plants require energy to live and grow. They obtain this energy from light needed for the process of photosynthesis in which food is manufactured. The green plants produce glucose (basic material) through photosynthesis using carbon dioxide (CO_2) and water (H_2O) under bonding of energy from the light in the presence of chlorophyll. Oxygen is released in this process. Other food materials such as carbohydrates, mainly starch, proteins, fats, vitamins, pigments, enzymes, hormones, organic acids, alcohol and other organic materials are formed from this basic material (glucose). These food materials play important role in the growth and development of vegetable crops and ultimately for final harvest.

The quality, intensity and duration of light influence the plant growth. The light quality refers to the length of waves. The visible part of spectrum ranges from wave length 390–730 nanometre (nm) which is white light. White light is composed of blue and red portions of spectrum. Normal plant growth requires white light or sunlight. The blue and red portions of the light spectrum are absorbed by chlorophyll. The light affects the rate of growth as measured in terms of dry weight. For example, tomato plant grown in red or blue light produces a greater dry weight. Red light in the range of 640–670 nm promotes the germination of lettuce seeds.

Light intensity refers to the number of photons falling on given area or to the total amount of light which plants receive. Most agricultural plants require 6 or more hours of full sunlight on sunny days for optimum productivity. If the plants are grown under shade, they produce less yield. However, some plants grow well in shade or semi-shade places. All vegetable crops prefer full sunlight. However, some of them such as leafy vegetables can tolerate shade.

Duration of light (day-length) or number of day light hours, is most important for the growth and development of vegetable crops. Generally, light duration is shorter in winter than in summer. Winter days are called short days and summer days are known as long days. The response of crop plants to length of day is called photoperiodism, whereas the length of exposure period of plants to light is known as photoperiod. Rubatzky and Yamaguchi (1997) defined photoperiodism as the

flowering response of plants to the relative length of the light period or its absence. Plants have been classified based on their photoperiodic responses into 3 groups:

Long-day (short night) plants: Long-day plants flower when the length of photoperiod is more than 14 hours, e.g., Spinach, Chinese cabbage, radish, carrot, beet root, lettuce, celery, turnip, chard, onion, garlic.

Short-day (long night) plants: Short-day plants flower when the photoperiod is less than 10 hours, e.g., Sweet potato, chow-chow, potato, yams, cassava.

Day-neutral plants: Day-neutral plants flower without responding to the photoperiod (length of day). e.g., Cucurbits (other than chayote,), tomato, bell pepper, brinjal, cabbage, cauliflower, sweet-corn, beans, potato, onion, carrot, beet, turnip, radish.

Length of the day not only influences the flowering of the vegetable crops but also the formation of storage organs. Different vegetable crops respond differently to photoperiod in the formation of underground storage organs (Swiader *et al.* 1994).

According to Swiader *et al.* (1994) the length of the light and dark-period affect plant growth and development in the following 2 ways:

1. It determines the relative amount of carbohydrates or net photosynthetic products made by all the cropsm and
2. It regulates the time of flower bud formation of many crops and the time of initiation of storage organs of such crops as onions, garlic, potato and sweet potato.

Long-day-length results in high rate of net photosynthesis, favouring high growth and yield.

Moisture: Water comprises more than 80% of the living plants, providing structural integrity for the plant. Rainfall is the natural source of water. Water is a major determinant of crop productivity and quality. Water is required in large quantities for plant growth than any other of the growth factor. Water is a solvent for nutrients, minerals, etc. Water improves the germination of seeds. Water is essential to establish transplanted seedlings. Water is essential for faster establishment of the crop. Water is essential to facilitate application and distribution of fertilizers and pesticides. Water provides protection in cold temp nature (frost). Water facilitates harvesting of underground crops in dry soils. It helps cooling of the leaves during respiration. All crops have moisture range at which crop response is optimum. Crops differ in their tolerance of continuous wet conditions. e.g., hydrophytes – aquatic; mesophytes – most common of terrestrial plants; and xerophytes- can endure long dry periods.

Root systems affect the amount of water uptake. Negative aspects of rainfall are, waterlogging, drought and storms. The amount and annual distribution of rainfall (precipitation) in a region, especially during certain periods of development, affects local crops. Irrigation may be required to compensate for insufficient rainfall. For optimum growth and development, plants require soil that supplies water as well as nutrients dissolved in water. Root growth determines the extent of a plant's ability to absorb water and nutrients, and in dry soil root growth is greatly retarded. Extremely wet soil also retards root growth by restricting aeration. Atmospheric humidity, the moisture content of the air, also contributes moisture. Certain sea-coast areas characterized by high humidity are considered-

especially adapted to the production of such crops as the artichoke and lima bean. High humidity, however, also creates conditions favourable for the development of certain plant diseases.

Humidity: The growth of plant is affected both by soil moisture and water vapours in the air (humidity). The water vapour in the air is usually expressed as relative humidity (RH), the percentage of moisture which the air holds at a given time compared to the maximum it could hold at the temperature existing at the same time. Relative humidity has strong influence on evapotranspiration. The loss of water from the surface of plants and soil and through stomata decreases with the increase in relative humidity. Besides, the rate of photosynthesis in plants also increases with the increase in humidity. Some of the effects of high relative humidity on plants are, i) it favours vegetative growth and operates against seed ripening; ii) it prevents wilting of leafy vegetables, particularly after harvest; iii) it favours the outbreak of pests and certain diseases.

Vegetative growth increased with the increase in humidity, resulted in greater yield of economic products. It is well known that humidity in combination with temperature greatly influences the growth and reproduction of vegetable crops. Cole crops (caulifower, cabbage and kholrabi), spinach and beet root require cool humid places for seed production, whereas, dry conditions with high temperature is favourable for seed production of onion, radish and cucurbits. Staminate flowers are favoured by low humidity, whereas high humidity favours pistillate flowers. Dry weather and low humidity is favourable for seed maturity and harvesting of seed crops.

Wind**:** A slight wind is necessary to replenish carbon dioxide near plant surface. Wind carries oxygen away from the plant. Less wind, less evaporation, less water requirement may aid in pollination. Wind can be a limiting factor in vegetables production where strong winds occur (average wind speed of 7.2 km/hr). e.g., Typhoons (wind speed of 60 km/hr). Use of windbreaks (shelter belts) minimize damage; a relatively slow wind.

Each of the climatic factors affects plant growth, and can be a limiting factor in plant development. Unless each factor is of optimum quantity or quality, plants do not achieve maximum growth. In addition to the importance of individual climatic factors, the interrelationship of all environmental factors affects growth.

Certain combinations may exert specific effects. Lettuce usually forms a seedstalk during the long-days of summer, but the appearance of flowers may be delayed, or even prevented, by relatively low temperature. An unfavourable temperature combined with unfavourable moisture conditions may cause the dropping of the buds, flowers, and small fruits of the pepper, reducing the crop yield. Desirable areas for muskmelon production are characterized by low humidity combined with high temperature. In the production of seeds of many kinds of vegetables, absence of rain, or relatively light rainfall, and low humidity during ripening, harvesting, and curing of the seeds are very important.

Site and soil factors

Site

The choice of a site involves such factors as soil and climatic region. In addition,

with the continued trend toward specialization and mechanization, relatively large areas are required for commercial production, and adequate water supply and transportation facilities are essential. Topography, that is, the surface of the soil and its relation to other areas influences efficiency of operation. In modern mechanized farming, large, relatively level fields allow for lower operating costs. Power equipment may be used to modify topography, but the cost of such land renovation may be prohibitive. The amount of slope influences the type of culture possible. Fields with a moderate slope should be contoured, a process that may involve added expense for the building of terraces and diversion ditches. The direction of a slope may influence the maturation time of a crop or may result in drought, winter injury, or wind damage. A level site is generally most desirable, although a slight slope may assist drainage. Exposed sites are not suitable for vegetable farming because of the risk of damage to plants by strong winds.

Soil aeration

Good soil aeration is a prime requirement for proper plant growth. Plant roots need sufficient air (O_2) for proper respiration which is essential for water and ion uptake by roots. Researchers have found that the respirational behaviour of roots, tubers and other underground parts was slowed down or stopped in the absence of O_2. It is reported that poor soil aeration reduces the root growth. Under such conditions, roots are thicker, shorter, darker and have fewer than normal root hairs whereas, in well-aerated conditions, roots are long, light and well supplied with root hairs. Soil aeration also plays an important role in plant survival in the early stages of plant growth; germination and growth of some vegetables were seriously inhibited by reduced aeration. Poor aeration may result in poor shoot growth, ultimately in reduced yield; suppressed growth with reduced O_2 concentration in the soil air in sweet potato, cucumber, maize, Chinese cabbage and Japanese radish. Low O_2 content in soil also decreases water uptake by plants because poor aeration reduces the root permeability to water.

Soil moisture (water)

Water is essential for plant growth particularly during the actively growing phase which constitutes about 80 to 95% of the total fresh weight of most of the vegetable crops. The water content of various plant tissues is given in Table 13 (Nath *et al.* 2002). Water is constantly being lost through evapotranspiration and absorbed from the soil by the root system. This constant movement of water through plant is essential for its survival. The transpiration stream carries essential nutrients from the soil to the sites where they are needed in the shoot for growth and development. Also water flow permits the translocation of

Table 13. Water content in various plant parts of some of the vegetable crops expressed as a percentage of fresh weight

Plant parts	Crop	Water content (%)
Roots	Carrot	88.2
Stems	Asparagus tips	88.3
Leaves	Cabbage mature Lettuce inner leaves	86.094.8
Fruits	Tomato fruitWater melon	94.192.1
Seeds	Sweet corn – mature	84.8

photosynthates produced in the leaves to other parts of the plant to support new growth or for storage (Harper, 1983). This shows that water-holding capacity of the soil essentially plays very important role in the crop growth and development and ultimately yield potential of the crop. If there is insufficient moisture in the soil or the transpiration rate is high, and the plants are unable to compensate for the loss and hence, plants come under water stress. Under water stress, plants show wilting symptoms. If water is made available to plants by means of irrigation before permanent wilting of plants, there is no loss in productivity of the crop. Otherwise, final yield and quality of the vegetable crops are affected. Water is essential during critical growth periods of vegetable crops. If water stress occurs during critical stages of growth, yield is directly affected. When moisture requirements are not met during this critical phase, it results in permanent damage (Monnecke, 1989). Vegetable crops have different critical growth periods. Critical growth stages of different vegetable crops for soil water stress is furnished in Table 14 (Nath *et al.* 2002).

Water supply (irrigation) and management are very essential to reduce the loss in yield and quality of vegetable crops. The knowledge of the physical distribution of plant root-system will assist in the management of water balance in vegetables. Based on the average feeder root depth vegetable crops are categorized into three groups, namely shallow rooting, medium rooting and deep rooting crops (Table 15) (Nath *et al.* 2002). Soil preparation and water supply should match the needs of the root-systems.

Table 14. Critical growth stages of different vegetable crops for soil water stress

Crops	Critical stages
Asparagus	Fern growth
Bean (all)	Flowering and pod formation
Broccoli	Head formation and enlargement
Cabbage	Head formation and enlargement
Carrot	Root enlargement
Cauliflower	Frequent irrigation essential from planting to harvest
Celery	Establishment and during rapid growth
Cucumber	Flowering and fruit enlarging
Eggplant	Flowering and fruit enlarging
Lettuce	Head developing
Muskmelon	Flowering and fruit developing
Onion	Bulbing and enlarging
Peas	Flowering and pod filling
Pepper	Transplanting, fruit setting and developing
Potato	Any growth period under water stress from plant to harvest
Pumpkin	Flowering and fruit developing
Radish	Root enlarging
Summer squash	Flowering and fruit development
Sweet-corn	Tasseling, silking and ear filling
Tomato	Flowering, fruit setting and enlarging
Watermelon	Blossoming to harvesting

Table 15. Vegetable crops with average feeder root depth

Shallow rooting (Less 0.67 m)	Medium rooting (0.68–1.0 m)	Deep rooting (1.0–2.0 m or than more)
Broccoli	Celery	Tomato
Beans	Cucumber	Lettuce
Artichoke	Pumpkin	Pepper
Brussels sprout	Chinese cabbage	Water melon
Beet	Eggplant	Onion
Asparagus	Winter squash	Summer squash
Cabbage	Garlic	Potato
Carrot	Mustard	Turnip
Lima Bean	Sweet potato	Radish
Cauliflower	Leek	Spinach
Chard	Pea	Sweet-corn
Muskmelon		

Water is not only essential for growth and development of vegetable crops but is also a prime requirement for seed germination. Water requirement during germination has 3 phases, viz., (*i*) a large initial absorption causes seeds to swell and begin the germination process, (*ii*) a low water requirement period as the chemical changes associated with germination take place, (*iii*) a high water requirement as the root emerges and the seedling develops.

Vegetable crops can be grouped into 4 classes in response to the effects of soil moisture on seed germination, viz., (*i*) Seeds that will germinate in soil with moisture slightly above the permanent wilting percentage to field capacity are cabbage, onion, squash, musk melon, pepper, tomato, sweet-corn, radish, spinach, turnip, cucumber and water melon; (*ii*) Seeds that will germinate in soils with intermediate moisture to field capacity are, lima bean, beet, lettuce, snap bean and peas; (*iii*) Seeds that will germinate only in soils near field capacity is celery; (*iv*) Seeds that germinate at lower soil moisture but have restricted germination near field capacity is New Zealand spinach.

Vegetables can be grouped according to their water requirement into four groups, viz., (*i*) vegetables having high water requirement- *palak*, amaranths, lettuce, celery, other leafy greens, sweet pepper, cabbage, cauliflower, broccoli, brussels sprouts, radish, turnip, rutabaga, green onion; (*ii*) vegetables having moderate water requirement- onion, cucumber, chilli, brinjal, tomato, carrot, potato; (*iii*) vegetables having low water requirement- peas, French bean, broad bean, cluster bean, winged bean, hyacinth bean, asperagus, rhubarb, horse radish, beet, ridge-gourd; and (*iv*) vegetables having very low water requirement- water melon, musk-melon, pumpkin, ash-gourd. The water requirement is expressed as the units of absorbed water required for the production of one unit of dry matter.

Soil nutrition

The soil is a crop growing media consisting of all plant nutrients essential for the growth and development of the crop plant. Vegetable crops generally grow in good fertile soils with continuous supply of nutrients and moisture. Soil fertility refers to the capacity of soil to deliver the essential nutrient elements to the plants. These nutrients are essential to sustain the physiological processes controlling growth and development. Some nutrients are needed in large quantity by plants called major nutrients and others are required in small quantity known as minor or trace elements. The elements C, H, O and N are derived from atmosphere while K, Ca, Mg, P, S, Fe, Cu, Mn, Zn, Mo, B and Cl are constituents of the parent rock from which soil is formed. The elements constituting the major building blocks of the plants are, C, H, O, N and P. The cell-wall, carbohydrates and fats are composed of C, H, and O. Proteins are composed mainly of C, H, O and N. The nucleic acids of the nucleus and cytoplasm are made of C, H, O, N and P. Potassium activates several important enzymes. Calcium forms insoluble salts with the acidic pectins to form calcium pectate which binds cells together and gives rigidity to plants. Magnesium is an essential part of the chlorophyll. Sulphur is a constituent of several amino acids. Fe, Cu, Mn, Zn and Mo function as co-enzymes. Boron is essential for meristematic cells, while chlorine stimulates photosynthetic phosphorylation. If the soil lacks in the availability of these

nutrients, they are supplied to the plants through manures and fertilizers added to the soil. The yield and the nutrients removal from the soil by some of the vegetable crops is given in Table 16 (Nath *et al.* 2002).

Table 16. Removal of primary nutrients from the soil by some of the vegetable crops

Crop	Yield (tonne/ha)	Nutrient removal (kg/ha)		
		N	P	K
Potato	40	175	80	310
Tomato	50	140	65	190
Brinjal	60	175	40	300
Cabbage	70	370	85	480
Cauliflower	50	250	100	350
Knol khol	20	100	84	170
Carrot	30	125	55	200
Radish	20	120	60	120
Beet	25	60	40	112
Onion	35	120	50	160
Leek	30	102	50	160
Cucumber	40	70	50	120
Pumpkin	50	90	70	160
Musk melon	15	54	16	97
Peas	9	124	44	88
Beans	15	130	40	160
Okra	20	60	25	90
Celery	30	200	80	300
Lettuce	30	90	35	160
Spinach	25	120	45	200
Asparagus	5	120	60	150
Cassava	40	150	70	350
Sweet potato	40	190	75	340
Elephant foot yam	50	170	40	245
Yam	14	80	20	86

N, Nitrogen; P, Phosphorus; K, Potasium

Soil pH

The soil stores mineral nutrients and water used by plants, as well as housing their roots. There are two general kinds of soils; mineral and the organic type called muck or peat. Mineral soils include sandy, loamy, and clayey types. Sandy and loamy soils are usually preferred for vegetable production. Soil reaction and degree of fertility can be determined by chemical analysis. The reaction of the soil determines to a great extent the availability of most plant nutrients. The degree of acid, alkaline, or neutral reaction of a soil is expressed as the pH, with a pH of 7 being neutral, points below 7 being acid, and those above 7 being alkaline. The optimum pH range for plant growth varies from one crop to another. A soil can be made more acidic, or less alkaline, by applying an acid producing chemical fertilizer such as ammonium sulphate.

The inherent fertility of soils affects production quantity, and a sound fertility program is required to maintain productivity. The ability of a soil to support plant life and produce abundant harvests is dependent on the immediately available nutrients in the soil and on the rate of release of additional nutrients that are present but not available to plants. The rate of release of these additional nutrients is affected by such factors as microbial action, soil temperature, soil moisture, and soil aeration. Depletion of soil fertility may occur as a result of removal by the crop, erosion, leaching, and volatilization, or evaporation, of nutrients.

The availability of plant nutrients in the soil is affected by the soil reaction (soil pH) as under:

Soil pH - 6.5–7.0 (normal): Almost all nutrients are readily available.

Soil pH below 6.5 (acidic): Phosphorus, magnesium, molybdenum and calcium are not available.

Soil pH above 7.0 (saline): Iron, manganese, boron and zinc become unavailable.

A low soil pH is usually associated with high level of Al and Mn in the soil

solution. These elements in excess are toxic to plants. Toxic level of Al restricts root development, resulting in low uptake of nutrients and water.

The relative tolerance of different vegetable crops to soil acidity is given here:

Less tolerant (pH 6.8–6.0): Asparagus, beet, broccoli, cabbage, cauliflower, celery, spinach, Swiss chard, cress, knol khol, onion, lettuce, muskmelon, New Zealand spinach, okra, onion, parsnip, salsify, spinach, water-cress.

Moderately tolerant (pH 6.8–5.5): French bean, lima bean, brussels sprouts, carrot, collard, cucumber, brinjal, garlic, horse radish, cabbage, water melon, parsley, peas, chilli, pumpkin, radish, rutabaga, summer squash, winter squash, tomato, turnip.

Highly tolerant (pH *6.8–5.0):* Fennel, potato, rhubarb, shallot, sweet potato, kale, leek.

Soil preparation and management

Soil preparation for vegetable growing involves many of the usual operations required for other crops. Good drainage is especially important for early vegetables because wet soil retards development. Sands are valuable in growing early vegetables because they are more readily drained than the heavier soils. Soil drainage accomplished by means of ditches or drainage channels is more desirable than the drainage obtained by planting crops on ridges because the former not only removes the excess water but also allows air to enter the soil. Air is essential to the growth of crop plants and to certain beneficial soil organisms making nutrients available to the plants.

When crops are grown in succession, soil rarely needs to be ploughed more than once each year. Ploughing incorporates sod, green-manure crops, and crop residues in the soil; destroys weeds and insects; and improves soil texture and aeration. Soils for vegetables should be fairly deep. A depth of six to eight inches (15–20 cm) is sufficient in most soils.

Soil management involves the exercise of human judgment in the application of available knowledge of crop production, soil conservation and economics. Management should be directed toward producing the desired crops with a minimum of labour. Control of soil erosion, maintenance of soil organic matter, the adoption of crop rotation, and clean culture are considered important soil-management practices.

Soil erosion, caused by water and wind, is a problem in many vegetable-growing regions because the topsoil is usually the richest in fertility and organic matter. Soil erosion by water can be controlled by various methods. Terracing (terrace cultivation) divides the land into separate drainage areas, with each area having its own waterway above the terrace. The terrace holds the water on the land, allowing it to soak into the soil and reducing or preventing gullying. In the contouring system, crops are planted in rows at the same level across the field. Cultivation proceeds along the rows rather than up and down the hill. Strip cropping consists of growing crops in narrow strips across a slope, usually on the contour. Soil erosion by wind can be controlled by the use of windbreaks of various kinds, by keeping the soil well supplied with humus, and by growing cover crops to hold the soil when the land is not occupied by other crops.

Maintenance of the organic matter content of the soil is essential. Organic matter is a source of plant nutrients and is valuable for its effect on certain properties of the soil. Loss of organic matter is the result of the action of microorganisms that gradually decompose it to carbon dioxide. The addition of manures and the growing of soil-improving crops are efficient means of supplying soil organic matter. Soil-improving crops are grown solely for the purpose of preparing the soil for the growth of succeeding crops. Green-manure crops, grown especially for soil improvement, are turned under while still green and usually are grown during the same season of the year as the vegetable crops. Cover crops, raised for both soil protection and improvement, are only grown during seasons when vegetable crops do not occupy the land. When a soil-improving crop is turned under, the various nutrients that have contributed to the growth of the crop are returned to the soil, adding a quantity of organic matter. Both legumes (legume), those plants such as peas and beans having fruits and seeds formed in pods, and non-legumes are effective soil-improving crops. The legumes, however, are more valuable, because they contribute nitrogen as well as humus. The rate of decomposition of plant material depends on the kind of crop, its stage of growth, and soil temperature and moisture. The more succulent the material is at the time it is turned under, the more quickly it decomposes. Because dry material decomposes more slowly than green material, it is desirable to turn under soil improving crops before they are mature, unless considerable time is to elapse between the ploughing and the planting of the succeeding crop. Plant material decomposes most rapidly when the soil is warm and well supplied with moisture. If soil is dry when a soil improving crop is turned under, little or no decomposition will occur until rain or irrigation supplies the necessary moisture.

The chief benefits derived from crop rotation are the control of disease and insects and the better use of the resources of the soil. Rotation is a systematic arrangement for the growing of different crops in a more or less regular sequence on the same land. It differs from succession cropping in that rotation cropping covers a period of two, three, or more years, while in succession cropping two or more crops are grown on the same land in 1 year. In many regions vegetable crops are grown in rotation with other farm crops. Most vegetables grown as annual crops fit into a 4 or 5 year rotation plan. The system of intercropping or companion cropping, involves the growing of two or more kinds of vegetables on the same land in the same growing season. One of the vegetables must be a small-growing and quick-maturing crop; the other must be larger and late maturing.

In the practice of clean culture, commonly followed in vegetable growing, the soil is kept free of all competing plants through frequent cultivation and the use of protective coverings or mulches, and weed killers. In a clean vegetable field the possibility of attack by insects and disease-incitant organisms, for which plant weeds serve as hosts, is reduced.

Propagation

Propagation of crop plants, involving the formation and development of new individuals in the establishment of new plantings, is usually accomplished by the use of either seeds or the vegetative parts of plants. The first type, known as

sexual propagation, is used for asparagus, bean, broccoli, cabbage, carrot, cauliflower, celery, cucumber, brinjal, leek, lettuce, lima bean, okra, onion, musk melon, parsley, pea, sweet pepper, pumpkin, radish, spinach, sweet-corn, squash, tomato, turnip, and watermelon. The second type, asexual propagation, is used for the chayote, Ivy-gourd, artichoke, garlic, potato, rhubarb, and sweet potato.

Although seed (seed and fruit) cost is a small portion of the total cost of crop production, seed quality strongly affects crop success or failure. Good seed should be accurately labelled, clean, graded to size, viable, and free of diseases and insects. The reliability of the seed house is an important factor in obtaining good-quality seed. Viability, or ability to grow, and longevity, the period of viability, are characteristics of seeds of any vegetable kind. In cool, dry storage conditions, those vegetable seeds having comparatively short longevity of 1 to 2 years are okra, onion, parsley, and sweet-corn. Seeds having 3-year longevity are those of the asparagus, bean, carrot, leek, and pea; 4-year longevity is characteristic of the beet, chard, pepper, pumpkin, and tomato seeds; longevity of 5 years characterizes the seeds of broccoli, cabbage, cauliflower, celery, cucumber, eggplant, lettuce, muskmelon, radish, spinach, squash, turnip, and watermelon. The dry seeds of all vegetables, when packed under vacuum in hermetically sealed cans, should remain viable for a longer period than seeds stored under less protective conditions.

Crops grown from hybrid seeds (F_1) yield vegetables of high quantity and quality. The hybrid seed industry is based on the production of new seed each year from the controlled pollination of selected parents found to produce the desired combination of characters in the progeny. The number of F_1 hybrids varied with the kind of vegetable, but none had yet been introduced for the bean, celery, lettuce, parsley or pea.

Sowing and planting

Most vegetable crops are planted in the field where they are to grow to maturity. A few kinds are commonly started in a seedbed, established in the greenhouse or in the open, and transplanted as seedlings. Asparagus seeds are planted in a seedbed to produce crowns used for field setting. Some vegetables can be either directly seeded in the field or grown from transplants. These include broccoli, cabbage, cauliflower, celery, brinjal, leek, lettuce, onion, pepper and tomato. The time and method of planting seeds and plants of a particular vegetable influence the success or failure of the crop. Important factors include the depth of planting, the rate of planting, and the spacing both between rows and between plants within a row.

Factors to be considered in determining the time of planting include soil and weather conditions, kind of crop, and desired harvest time. When more than one planting of a crop is made, the second and later plantings should be timed to provide a continuous harvest for the period desired. The soil temperature required for germination of the planted seed varies markedly with the various kinds of vegetables. Vegetables that will not germinate at a temperature below 16°C include the bean, cucumber, eggplant, lima bean, muskmelon, okra, pepper, pumpkin, squash and watermelon. Temperatures higher than 32°C are not favourable for the germination of seeds of celery, lettuce, lima bean, parsley, pea and spinach.

The quantity of seeds planted, or rate of planting, is mainly determined by the

characteristics of the vegetable plant. The size of seeds affects the number of plants raised in a given area. Watermelon varieties, for example, differ in seed size expressed as weight. The 'Sugar Baby' variety has an average weight of 41 g for 1,000 seeds; those of local variety average 125 g. If the 2 are grown on 2 separate plots of the same area and 125 g seeds of each cultivar are planted, the result would be 3 times as many of the 'Sugar Baby' plants as the local type. Seed size and plant growth pattern of a vegetable are major factors that govern the number of plants raised in a given area. As plant population increases per unit area, a point is reached at which each plant begins to compete for certain essential growth factors— e.g., nutrients, moisture and light. When the population is below the level in which competition between plants occurs, increased population will have no effect on individual plant performance, and the yield per unit area will increase in direct proportion to the increment of population. When competition for essential growth factors occurs, however, yield per plant decreases.

Early harvest and economical use of space are the principal objectives of growing vegetable crops from transplants produced in a nethouse or greenhouse or outdoor seedbed. It is easier to care for young plants of the cabbage, cauliflower, celery, onion and tomato in small seedbeds than to sow the seeds in the place where the crop is to grow and mature. Land is free longer for another crop, and weeds, insects, diseases, and irrigation are more readily and economically controlled. The production of transplants is often a specialty of growers who sell their produce to other vegetable growers. The young plants are removed for use as transplants when they reach the desired size and age, approximately 30–40 days after seeding.

Raising of seedlings in raised nursery beds: Majority of vegetables crops are propagated by seeds, except a few like coccinia, pointed gourd, *kakrol*, sweet potato, asparagus, garlic and potato, which do better if propagated by cuttings, roots, cloves and tubers. Among the vegetable crops which are propagated by seeds, most of them like cucurbits, beans, peas, radish, turnip, carrot, leafy vegetables and okra are required to be sown directly in the field, whereas crops like tomato, brinjal, capsicum, chilli, cabbage, cauliflower, knol-khol, lettuce, brussels sprouts and onion and some cucurbits (of late) are first sown in nursery-beds where seedlings are raised and then transplanted. Proper nursery management for raising seedlings and transplanting them are important operations in vegetable production.

A nursery has the following advantages:

1. It is very convenient to look after the tender seedlings.
2. Timely and careful plant-protection measures are possible.
3. Most favourable growth medium is provided.
4. Seedlings are in a protected place and usually timed for early crop.
5. It ensures uniform growth and establishment of plants in the field.
6. There is economy of land and seed, and more time is available for field preparation.

The following points are to be considered before laying out the nursery:

1. The soil of the land should be sandy loam and normal in *p*H (6.5–7.0).
2. Land for nursery should be well-drained and located on a elevated level.

3. Nursery plots should be selected near farm buildings for frequent and easy supervision.
4. The plot for nursery should be selected near water source.
5. Nursery plot should be away from the shady places.
6. Nursery plots should be selected at one side of the field to isolate the other field for doing cultural practices easily.

While preparing nursery bed, the soil should be worked to a fine condition (tilth) by repeated ploughing and spading. Dead roots and weeds are collected, removed and burnt. Well-decomposed organic manure @ 40–50 kg/10 m^2, should be mixed thoroughly in the soil. Damping off is a common disease in the seedbeds. This is a soil-borne-fungal disease, if attacked, seedlings dry up at ground level and topple over. The control measures are sterilization of the nursery soil and treatment of seeds with fungicides like ceresan, thiram or emisan before sowing. Drenching the soil with formaldehyde @ 25 ml/l water and covering them with polythene sheet after drenching for a week or so, is very effective to check the attack of damping off. This treatment should be given one month prior to sowing. Termites and cutworms damage young seedlings by cutting them at the base near the soil. This problem can be controlled by treating the soil with suitable insecticides before sowing or at the time of nursery preparation. Before finally preparing the bed, soil should be levelled and pressed gently to make it firm. Raised beds are always preferred and these should be made 10–15 cm higher from the surface level. The height of the beds depends on the soil conditions, rainfall, drainage facilities, etc. The length of the beds may be made according to the requirement or size of the plots. But these should not be made more than 50 cm wide for proper care and operations. Drains of 30 cm wide and 8–10 cm deep are prepared around and in between the beds, connecting to the main drains to remove the excess water. These drains are flooded during summer season to supply moisture and coolness to the young seedlings. These inter-spaces are also used for hand watering, weeding and lifting of seedlings.

The common practice is to broadcast seeds in the nursery bed but line sowing is preferred so as to check proper germination and to facilitate weeding, hoeing and plant-protection operations. The seeds are treated before seeding with fungicides like thiram or captan @ 2.5 g/kg of seeds as a precaution against damping-off disease which is common in warm nursery. They may be drenched with captan (0.2%) solution. The rows are usually kept about 5 cm apart. The size of the nurserybed to raise seedlings to plant 1 ha of tomato, brinjal and capsicum would be 50 m × 1.2 m, 54 m × 1.2 m and 180 m × 1.2 m, respectively. In case of cole crops like cauliflower, cabbage and knol-khol, a nurserybed of 115 m × 1.2 m would be sufficient to raise seedlings for 1 ha plot. These could be made into smaller beds instead of making a single bed. Small seeds should be sown mixed with a little sand and covered with soil. This covering should be still lighter in heavy soils. Covering the seeds in furrows or rows may be done gently by fingers or with the aid of a wooden strip, followed by a light irrigation with a watercan or sprinkler.

In the beginning, if the sun is too warm, the mid-day sun may be avoided by covering the seedlings with a thin a layer of straw, leaves, twigs or thatch. During

summer, the seedlings may be protected against warm wind and sunshine. When the seedlings are more than 2.5 cm tall, too much of shade and water make them yellow, succulent, lanky and susceptible to insect-pests and diseases, like damping off, especially in humid and warm weather. The diseased plants should be removed immediately. A week before transplanting, the seedlings may be exposed to full sunshine and the number of waterings reduced so that the seedlings become hardy to bear the shock of transplanting.

Watering of the bed is done uniformly and gently to avoid a packing of the soil or washing away of the soil covering. It is always advisable to make the nurserybed near the source of irrigation water.

Raising of seedlings in portrays or plugtrays: Vegetable nurseries generally grow the seedlings of F_1 hybrid vegetables in small trays which are gradually replacing the open-pollinated varieties. Each seedling is sold @ ₹ 0.50 to 2.00 based on the crop and variety. Specialized companies and progressive farmers produce vegetable seedlings to supply high-quality seedlings to the vegetable growers. Since the hybrid seeds are expensive, the tray-grown vegetable seedlings are becoming popular, as this method of raising the seedlings minimizes the loss of seeds and seedlings as against flat bed or raised bed nurseries.

The seedling trays are known as protrays, flattrays and plugtrays. These trays made of polypropylene can be reused up to 6 times to grow seedlings. Before using every time it is necessary that these trays are thoroughly washed and disinfected with a fungicide. The holes at the bottom of the cells control the moisture properly. Equi-spaced cells facilitate even growth of the seedlings. Portrays with 98 cells are commonly used to raise the seedlings of tomato, capsicum, cabbage, cauliflower, chilli and brinjal. The size of the tray is generally 54 cm long and 27 cm wide (Anon., 2004d).

Transplanting of seedlings in the main field: If seedlings are allowed to grow too tall in the nursery-beds, they become weak and may start flowering. Transplanting should be done as soon as seedlings are about 4–8 weeks old, 10-15 cm long and have formed about 3- 4 true leaves. The bed must be watered 24 hours before uprooting the seedlings for transplanting, so that they may not suffer from desiccation.

Normally transplanting is done in the evening, so that plants may establish themselves in the cool weather at night and may recover from the shock of transplanting before the sunrise. Transplanting should be done as early as possible after carefully removing the plants from nursery without damaging the roots. It is advisable to transplant the seedlings in the evening or cloudy days particularly in summer. The soil should be prepared thoroughly before transplanting. Each seedling is placed vertically in the centre of the hole made in the field and the soil near the roots is pressed down with the fingers to make it firm. This may be followed by immediate watering. During transplanting, care should be taken to protect the seedlings against wilting by frequently sprinkling water on them and by covering the root zone by moist soil or leaves. Regular watering is necessary after transplanting. Seedlings not doing well may be removed and replaced by new ones. Any attack of disease or insect-pest must be controlled immediately. Sometimes, seedlings are transplanted twice. As soon as they begin to crowd

after the first transplanting, they are taken out and transplanted again in the field, spacing them further apart for proper growth and development. For example, cauliflower seedlings are sometimes transplanted twice to get stockier seedlings. Studies have shown that the hardening of cauliflower plants by repeated transplanting markedly improved the growth of plants in all respects and the yield of curd also increased considerably. However, double transplanting may damage seedlings and result in delayed maturity. Needless to say that double transplanting would naturally involve increased cost of production with whatever advantage it may have and that is why this system is not commonly practiced.

Care of vegetable crops during growth

Practices required for a vegetable crop growing in the field include cultivation; irrigation; application of fertilizers; control of weeds, diseases and insects; protection against frost; and the application of growth regulators if necessary.

Intercultivation: Intercultivation refers to stirring the soil between rows of vegetable plants. Because weed control is the most important function of cultivation, this work should be performed at the most favourable time for weed killing, when the weeds are breaking through the soil surface. When the plants are grown on ridges, it is necessary to cover the basal plant portion with soil in the case of such vegetables as asparagus, carrot, garlic, leek, onion, potato, sweet corn and sweet potato.

Irrigation: Vegetable production requires irrigation in arid and semi-arid regions, and irrigation is frequently used as insurance against drought in more humid regions. In areas having intermittent rain for 5 or 6 months, with little or none during the remainder of the year, irrigation is essential throughout the dry-season and may also be needed between rainfalls in the rainy season. The 2 types of land irrigation generally suited to vegetables are surface irrigation and drip irrigation. A level site is required for surface irrigation, in which the water is conveyed directly over the field in open ditches at a slow, non-erosive velocity. Where water is scarce, pipelines may be used, eliminating losses caused by seepage and evaporation. The distribution of water is accomplished by various control structures, and the furrow method of surface irrigation is frequently employed because most vegetable crops are grown in rows. Drip irrigation conveys water through pipes for distribution under pressure.

Irrigation requirements are determined by both soil and plant factors. Soil factors include texture, structure, water-holding capacity, fertility, salinity, aeration, drainage and temperature. Plant factors include type of vegetable, density and depth of the root-system, stage of growth, drought tolerance and plant population.

Fertilizer application: Soil fertility is the capacity of the soil to supply the nutrients necessary for good crop production, and fertilizing is the addition of nutrients to the soil. Chemical fertilizers may be used to supply the needed nitrogen, phosphorus and potassium. Chemical tests of soil, plant or both are used to determine fertilizer needs, and the rate of application is usually based on the fertility of the soil, the cropping system employed, the kind of vegetable to be grown, and the financial return that might be expected from the crop. Methods of fertilizer application include scattering and mixing with the soil before planting;

application with a drill below the surface of the soil at the time of planting; row application before or at planting time; and row application during plant growth, also called side-dressing. Ploughed down broadcast fertilizers have recently been used in combination with high-analysis liquid fertilizers applied at planting or as a side dressed band. Mechanical planting devices may employ fertilizer attachments to plant the fertilizer in the form of bands near the seed. For most vegetables, the bands are placed from 5–7.5 cm from the seed, either at the same depth or slightly below the seed.

Weed control: Weeds (plants growing where they are not wanted) reduce crop yield, increase production cost, and may harbour insects and diseases that attack crop plants. Methods employed to control weeds include hand-weeding, mechanical cultivation, application of chemicals acting as herbicides (herbicide), and a combination of mechanical and chemical means. Herbicides, selective chemical weed killers, are absorbed by the plant and induce a toxic reaction. The amount and type of herbicide that can be safely used to protect vegetable crops depends on the tolerance of the specific crops to the chemical. Most herbicides are applied as a spray, and the appropriate time for application is determined by the composition of the herbicide and the kind of vegetable crop to be treated. Preplanting treatments are applied before the crop is planted; pre-emergence treatments are applied after the crop is planted but before its seedlings emerge from the soil; and post-emergence treatments are applied to the growing crop at a definite stage of growth.

Pest and disease management: The production of satisfactory crops requires rigorous disease- and insect-control measures. Crop yield may be lowered by disease or insect attack, and when plants are attacked at an early stage of growth the entire crop may be lost. Reduction in the quality of vegetable crops may also be caused by diseases and insects. Grades and standards for market vegetables usually specify strict limits on the amount of disease and insect injury that may be present on vegetables in a designated grade. Vegetables remain vulnerable to insect and disease damage after harvesting, during the marketing and handling processes. When a particular plant pest is identified, the grower can select and apply appropriate control measures. Application of insect control at the times specific insects usually appear or when the first insects are noticed is usually most effective. Effective disease control usually requires preventive procedures.

Plant diseases are incited by such living organisms as bacteria, fungi and viruses. Harmful material enters the plant, develops during an incubation period, and finally causes infection, the reaction of the plant to the pathogen, or disease producing organism. Control is possible during the inoculation and incubation phases, but when the plant reaches the infection stage it is already damaged. Typical plant diseases include mildew, leaf spots, rust and wilt. Chemical fungicides may be used to control disease, but the use of disease-resistant plant varieties is the most effective means of control.

Vegetable breeders have developed plant varieties resistant to one or more diseases; such varieties are available for the bean, cabbage, cucumber, lettuce, muskmelon, onion, pea, pepper, potato, spinach, tomato, and watermelon.

Insects are usually controlled by the use of chemical insecticides that kill through

toxic action. Many insecticides are toxic to harmful insects but do not affect bees, which are valuable for their role in pollination.

Use of plant-growth regulators: It is sometimes desirable to retard or accelerate maturity in vegetable crops. A chemical compound may be applied to prevent sprouting in onion crops. It is applied in the field sufficiently early for absorption by the still-green foliage but late enough to avoid suppressing the bulb yield. Another substance may be used to end the dormancy, or rest period, of newly harvested potato tubers intended for planting. The treated seed potatoes have uniform sprout emergence. The same substance is applied to celery from 2–3 weeks before harvest to elongate the stalks and increase the yield and is also used to accelerate maturity in artichoke. A chemical compound, applied when adverse weather conditions prevail during the period of fruit setting, has been used to encourage fruit set.

Plant-growth regulators are well known to be involved in physiological processes governing growth and development of plants. They include artificially produced (synthetic) substances and phytohormones (produced in plants). There are 5 major groups of endogenous growth substances present in plants, viz. auxins, gibberellins, cytokinins, ethylene and abscisic acid. Auxins, gibberellins and cytokinins are growth-promoters and abscisic acid and ethylene are growth retardants. These substances occur in small quantities and control many of the physiological processes involved in plant growth and development, viz.

Auxins [Indole 3 acetic acid (IAA)]: IAA stimulates elongation of the stem and root.

Gibberellins (GA_3): GA_3 increases cell-division and cell elongation, promotes growth of leaf, flower and fruit and also breaks dormancy and induces flowering.

Cytokinins (*Kinetic zeatin*): This stimulates cell-division, promotes seed development, breaks dormancy of seeds and buds and also delays senescence.

Ethylene: This regulates ripening and also stimulates growth of stem and root.

Abscisic acid (*ABA*): This induces leaf and fruit abscission and also induces dormancy.

Plant-growth regulators are used effectively for improving vegetable crop production.

Harvesting

Market maturity of vegetables: The stage of development of vegetables when harvested affects the quality of the product reaching the consumer. In some vegetables, such as the bean and pea, optimum quality is reached well in advance of full maturity and then deteriorates, although yield continues to increase. Factors determining the harvest date include the genetic constitution of the vegetable variety, the planting date, and environmental conditions during the growing season. Successive harvest dates may be obtained either by planting varieties having different maturity dates or by changing the sequence of planting dates of one particular variety. The successive method is applicable to such crops as broccoli, cabbage, cauliflower, muskmelon, onion, pea, sweet corn (maize), tomato and watermelon. Certain varieties of the carrot, celery, cucumber, lettuce, parsley, radish, spinach or summer squash can be sown in succession throughout most of

the year in some climates, thus prolonging the harvest period. Hand harvesting is employed along with various mechanical aids for broccoli, cabbage, cauliflower, muskmelon and pepper crops. Many vegetables grown for processing and some vegetables destined for the fresh market are mechanically harvested.

Storage: Fresh vegetables are living organisms, and there is a continuation of life processes in the vegetable after harvest. Changes that occur in the harvested, unprocessed vegetables include water loss, conversion of starches to sugars, conversion of sugars to starches, flavour changes, colour changes, toughening, vitamin gain or loss, sprouting, rooting, softening and decay.

Some changes result in quality deterioration; others improve quality in those vegetables that complete ripening after harvest. Post-harvest changes are influenced by such factors as kind of crop, air temperature and circulation, oxygen and carbondioxide contents and relative humidity of the atmosphere, and disease-incitant organisms. To maintain the fresh vegetable in the living state, it is usually necessary to slow the life processes, through avoiding death of the tissues, which produces gross deterioration and drastic differences in flavour, texture and appearance.

Storage of vegetables contributes to price stabilization by carrying over produce from periods of high production to periods of low production. It also extends the period of consumption of many kinds of vegetables. Storage conditions can contribute to the preservation of the natural living state of the edible portion and to the prevention of deterioration through control of temperature, relative humidity and the quality of the produce to be stored. Vegetables for storage must be free from mechanical, insect and disease injury and should be at the proper stage of maturity.

Common (unrefrigerated) storage and cold (refrigerated) storage are the methods generally employed for vegetables. Common storage, lacking precise control of temperature and humidity, includes the use of insulated storage houses, outdoor cellars, or mounds. Cold storage allows precise regulation of temperature and humidity and maintenance of constant conditions by use of a refrigeration and ventilation system. Temporary storage, suitable only for very brief storage periods, is frequently practiced in the shipping season when large lots are accumulated for carload or truck quantities. The refrigerator car or truck is a means of temporary storage used to protect produce while it is in transit. Short-term storage may last for 4–6 weeks. Economic factors, such as the probability that prices will increase later in the season, encourage long-term storage of such perishable vegetables as the onion, potato and sweet potato.

Premarketing operations and selling: Premarketing operations include washing, trimming, waxing, precooling, grading, prepackaging, packaging and marketing.

Vegetables often require washing after harvest to remove any adhering soil particles. Such vegetables as the beet, carrot, celery, lettuce, radish, spinach, and turnip are trimmed before washing to remove discoloured leaves or to cut back the green tops.

Waxing (wax) of the cucumber, musk melon, pepper, potato, sweet potato, and tomato gives the product a bright appearance and controls shrivelling through

reduction of moisture loss.

Precooling, the rapid removal of heat from freshly harvested vegetables, allows the grower to harvest produce at optimum maturity with greater assurance that it will reach the consumer at maximum quality. Precooling benefits the vegetable by slowing the natural deterioration that starts shortly after harvest, slowing the growth of decay organisms and reducing wilt by retarding water loss. The major precooling methods include hydrocooling, contact icing, vacuum cooling, and air cooling. In hydrocooling the vegetable is cooled by direct contact with cold water flowing through the packed containers and absorbing heat directly from the produce. In contact icing crushed ice is placed in the package or spread over a stack of packages to precool the contents. The vacuum cooling process produces rapid evaporation of a small quantity of water, lowering the temperature of the crop to the desired level. Air cooling involves the exposure of vegetables to cold air; the air must be as cold as possible for rapid cooling but not low enough to freeze the produce exposed to the direct air blast. The preferred method of precooling varies according to the physical characteristics of the vegetable. Hydrocooling is recommended for the asparagus, beet, broccoli, carrot, cauliflower, celery, muskmelon, pea, radish, summer squash and sweet corn (maize); cabbage, lettuce and spinach are suited to vacuum cooling; air cooling is preferred for bean, cucumber, brinjal, pepper, and tomato. After the produce is precooled, it is desirable to maintain low temperature by shipping in refrigerator cars or trucks, by storing in cold storage rooms, and by refrigeration in retail stores.

Uniformity in size, shape, colour and ripeness is of great importance in marketing any vegetable product, and can be secured through grading. The establishment of standard grades furnishes a basis of trade. Grade standards are based mainly on general appearance, size, trueness to type and freedom from blemishes and defects.

Prepackaging, or consumer packaging, has become a highly organized practice, often employing elaborate equipment. The product is placed in bags made of transparent film, trays or cartons overwrapped with transparent film, or mesh or paper bags. The packaging of produce in consumer packages lends itself to self-service in retail stores. The production region is often the most satisfactory location for prepackaging, especially when a packaging centre serves a large vegetable-growing area.

Master containers for consumer packages are commonly made of paperboard. Cartons, bags, baskets, boxes, crates and hampers of various kinds and sizes are all used in packaging vegetables for marketing. The type of container is selected to fit the kind of vegetable; it furnishes a convenient means for transport, loading, and stacking, with security and economy of space. Uniform product throughout the package is an important consideration in packing vegetables.

Producers sell vegetables through various retail (retailing) and wholesale (wholesaling) practices. Retail sales are made directly to the consumer, often through roadside stands. Many growers sell most of their produce at wholesale to retail stores, to various types of buyers on local markets in nearby cities, or in regional markets. Growers who are located long distances from markets sell largely

to wholesale dealers or jobbers. Some growers have contracts with processors. Wholesale marketing arrangements are also made through auction markets in the producing regions and through cooperative organizations of producers. •

CHAPTER 12

Principles of Vegetable Seed Production

PRODUCTION of genetically pure and quality pedigree seeds requires high technical skill and specialization. Seed production must be carried out under standard and well-organized conditions. The producer should be familiar with climatic factors, genetic factors and agronomic factors affecting vegetable seed production (Rashid and Singh, 2000; Anon., 2013a).

Climatic factors

Before seeds can be produced from vegetables it is necessary for the crop to flower. Flowering is required by the plant for sexual reproduction and maintenance of generation. The process of flowering is complex. Some plant species pass from vegetative phase to the reproductive phase with special requirement or stimulus, whereas in others such stimulus is not required. Species which have a special physiological requirement to pass from the vegetative phase to reproductive phase are generally either dependent on day length (photoperiod) or have a low temperature requirement (vernalization). Not only photoperiod and temperature but some other climatic factors, e.g., rainfall, wind, etc., are also responsible for best yield of high-quality seeds. The major environmental factors influencing vegetable seed production are, photoperiod, temperature, rainfall and wind.

Photo-period

Photoperiod influences vegetable seed production by affecting photosynthesis and day-length. Within the limits of each crop plant, the higher the light intensity, the higher will be the rate of photosynthesis required to manufacture the important constituents of the seed. Different crop plants have different requirements of photoperiodism. The transition from vegetative to the reproductive phase in some vegetable crop plants can occur only at the season when the days are of particular length, and if the plants are kept in the wrong day length, they remain in vegetative phase for longer time. Crop species of temperate regions tend to flower in the long days of summer, while tropical crop species require shorter days. Plants can be classified into 3 main groups according to the specific duration of light and dark requirement in each 24 hour period or cycle in order to initiate flower, viz. short day plants, long day plants and day neutral plants.

Short-day plants: This group includes species which will not flower unless the day light period is shorter than a particular critical time, which is between

10 and 12 hr, for example Amaranth spp., soybean, pepper (some varieties), kidney bean.

Long-day plants: These include plants which will flower only when the light period is greater than a critical time. The critical photoperiod for most long-day plants is between 12 and 14 hr, for example, spinach, radish, cabbage, cauliflower, broccoli, turnip, etc.

Day-neutral plants: This group does not have a specific day-length requirement for flowering, for example, tomato, brinjal, lettuce, cucurbits, carrot, etc.

Temperature

Some vegetable species do not initiate flowers until the plant has received a cold stimulus. The requirement of cold temperature stimulus for flowering is called vernalization, e.g., cabbage, brussel's sprout, beet, biennial radish, carrot, onion, etc. Depending upon the vernalization requirement, vegetable crops are grouped in to the following 3 classes:

Annuals: Vegetable species which do not have vernalization requirements for flower initiation, such crops produce flower and seed in the first year, e.g., tropical radish.

Biennials: Biennial plants tend to remain in vegetative stage in the first year of growth and they flower and produce seeds in the second year, e.g., beet root, carrot, cabbage and biennial radish etc. Most of the biennial plants require vernalization for flower initiation.

Perennials: Perennial plants survive for several years producing flowers and seeds each year. e.g., Ivy-gourd, pointed-gourd, asperagus, chow-chow.

Most vegetables are, however, annuals and biennials. Temperature significantly influences the transition from the vegetative to the reproductive phase of the crop species having specific critical temperature requirements for flowering. Not only the flowering, the prevailing temperature during growth and developmental phases of plant determine the final seed yield.

Rainfall

An appropriate balance between sufficient rainfall for crop growth and establishment and sufficiently dry conditions for satisfactory pollination and seed ripening is the most important factor in the vegetable seed production. Sufficient soil moisture must be ensured during flowering stage when the crop is moisture sensitive, owing to the reduced root growth. Seed viability can be seriously affected by high rainfall during the seed ripening period.

Wind

Excessive wind increases water loss from the crop and soil, prevents maximum activity of pollinating insects, carries wind borne pollen over long distances and increases loss of seed by enhancing shattering during seed ripening. Strong winds during the reproductive phase can cause severe crop losses through lodging, shattering and shedding of seed. On the other hand, gentle wind facilitates increased pollination in cross-pollinated crops.

Genetic factors

During the course of seed production, it is necessary to ensure that the product is true-to type. Genetic purity of a variety can deteriorate due to several factors during production cycle. The important factors of apparent and real deterioration of varieties are: developmental variations, mechanical mixtures, mutations, natural crossing, minor genetic variation, selective influence of diseases and technique of the plant breeder. Of these, mechanical mixture, natural crossing and selective influence of diseases are perhaps the most important reasons for genetic deterioration of varieties during seed production, followed by raising the seed crops in areas outside their adoption which may cause developmental variations and genetic shifts in varieties.

For the maintenance of varietal purity various methods have been suggested. The important safeguards for maintaining genetic purity during seed production are as under:

Control of seed source

The use of seed of an appropriate class and from an approved source is necessary for raising the seed crop. Four classes of seeds, namely breeder seed, foundation seed, registered seed and certified seed, have been defined by the Association of Official Seed Certification Agencies (AOSCA).

Breeder seed: Breeder's seed is the genetically pure seed produced by the concerned breeder or by the institution which is used for the production of foundation seed.

Foundation seed: Foundation seed is also genetically pure seed produced from breeder seed under strict supervision. Foundation seed is the source of registered and/or certified seed.

Registered seed: Registered seed is the progeny of foundation seed that is so handled as to maintain satisfactory genetic identity and purity, and that has been approved and certified by a certifying agency. This class of seed should be of a quality suitable for production of certified seed.

Certified seed: Certified seed is the progeny of foundation or registered seed. Certified seed is so handled as to maintain satisfactory genetic identity and purity and that has been approved and certified by the certifying agency.

In most varieties Breeder seed must be planted to produce Foundation seed. Foundation seed must be planted to produce Registered seed. Registered seed must be planted to produce Certified seed. In varieties where there is no Registered class, Foundation seed must be planted to produce Certified seed.

Crop rotation

Satisfactory intervals between related or similar crops is required to minimize the risk of plant material or dormant seeds remaining from the previous crops, which are likely to cross-pollinate or make admixture with the planned seed crop. In addition to these, the reasons for crop rotation include plant nutrition, maintenance of soil physical condition and minimizing the risk of soil-borne pests and diseases. In practice, therefore, attention must be paid to the numbers of years since a related crop was grown in the same soil.

Isolation

One major factor during the course of seed production is to ensure that the possibility of cross pollination between different cross compatible plots or fields is minimized. To prevent cross pollination, adequate isolation distance needs to be provided. This also assists in avoiding admixture during harvesting and the transmission of pests and pathogens from alternative host crops. Vegetable seed crops can be isolated by time and by distance.

Isolation by time: This type of isolation is possible within individual farms of multiplication stations. In this system seed production is arranged in such a manner that the cross compatible varieties are grown in successive years or seasons provided the rules regarding rotation are applied.

Isolation by distance: When isolation by time is not possible, then isolation by distance is to be followed. Isolation distance primarily depends on the nature of pollination of the crop. In general, highly cross pollinated and insect pollinated vegetable crops like onion, radish, cabbage, cauliflower and cucurbits require an isolation distance of 800–1,000 m, while wind-pollinated vegetables like spinach, beet, require isolation distance of about 2,000 m. Isolation distance also varies according to category of seeds like foundation and certified seeds. The minimum isolation distance required for various vegetable seed crops is furnished in Table 17.

Table 17. Minimum isolation distance requirements for vegetable seed crop

Crops	Minimum isolation distance (m)		The seed crop is to be isolated by the distance given in column 2 or 3 from fields of
	Foundation seeds	Certified seeds	
1	2	3	4
Potato	5	5	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Tomato	50	50	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Brinjal	200	100	Other varieties: the same variety not conforming to varietai purity requirements for certification.
Capsicum/chilli	400	200	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Dolichos bean, Cowpea,French bean,Cluster bean	50	25	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Garden pea	20	10	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Lettuce	50	25	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Kasuri methi	50	25	Other varieties: the same variety not conforming to varietal purity requirements for certification.

(contd...)

(Continued Table 17 from page 84)

1	2	3	4
Cabbage, Khol-khol	1,600	1,000	Other varieties: the same variety not conforming to varietal purity requirements for certification. Broccoli (including sprouting), Brussel's sprouts, cauliflower, collards and kale including *karam sag*, cabbage from knol-khol, knolkhol from cabbage
Cauliflower	1,600	1,000	Other varieties: the same variety not conforming to varietal purity requirements for certification. Broccoli (including sprouting), Brussel's sprouts, cabbage, knol-khol, collards and kale including *karam sag*.
Chinese cabbage	1,600	1,000	Other varieties: the same variety not conforming to varietal purity requirements for certification. Rutabaga, rape, mustard and turnip.
Garden beet, Spinach beet	1,600	1,000	Other varieties: the same variety not conforming to varietal purity requirements for certification. Swiss chard, sugar beet, garden beet from spinach beet, spinach beet from garden beet
Carrot	1,000	800	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Radish, Turnip	1,600	1,000	Other varieties: the same variety not conforming to varietal purity requirements for certification. Chinese cabbage, rape, mustard, and rutabaga for turnip
Onion	1,000	400	Other varieties: the same variety not conforming to varietal purity requirements for certification.
Okra	400	200	Other varieties: the same variety not conforming to varietal purity requirements for certification. Wild *Abelmoschus* spp.
Amaranthus	400	200	Other varieties: the same variety not conforming to varietal purity requirements for certification. Wild *Amaranthus* spp.
Cucurbits: Bitter-gourd, Bottle-gourd, Cucumber, Indian squash, (*tinda*), long melon, musk melon, pumpkin, ridge-gourd, snake-gourd, sponge-gourd, summer squash, water melon, winter squash	800	400	Other varieties: the same variety not conforming to varietal purity requirements for certification, wild *Cucurbita* spp. muskmelon from long melon, long melon from muskmelon, pumpkin from summer and winter squashes, summer and winter squashes from pumpkin.

Roguing of off-types in seed crop

The existence of off type plants in the seed crop is a potential source of genetic contamination. The removal of such plants is termed as roguing. Not only the off types but the diseased and abnormal plants are also to be removed. The number of roguing required for the seed crop will vary with the kind of vegetables, purity of the seeds sown, nature of the previous crop, etc. Roguing may be done at three stages, viz., vegetative stage, flowering stage and maturity stage, as soon as the off-types are recognizable. In the seed crop, off-type plants should be rogued out at different times of the day by walking in different directions of the plot. In general the cross pollinated vegetable crop for seed production should be thoroughly rogued before flowering. Regular supervision by trained manpower is important.

Seed certification

The genetic purity in the commercial seed production is maintained through a system of seed certification. Seed certification implies that the crop and seed lot have been duly inspected and that they meet requirement of good-quality pedigree seeds. To achieve this purpose, qualified and well-trained personnel of seed certification agencies carry out field inspection at appropriate stages of crop growth. They also make seed inspections to verify that the seed lot is of the requisite genetic purity and quality. In addition to inspections, seed certification agencies also lay down the field and seed standards which the seed crop and seed lot, respectively, must conform to get approval as certified seed. The field standards include land requirements, isolation requirements, maximum permissible off types etc.

Grow out tests: Varieties being grown for seed production should periodically be tested for genetic purity by grow out tests to make sure that they are being maintained in their true form.

Agronomic factors

Besides genetic principles of seed production, there involves the application of the following agronomic principles for the production of good-quality seeds.

Selection of suitable areas for seed production

The areas for seed production are based on climatic factors which ensure a relatively satisfactory environment for vegetable seed production. This factor includes moderate rainfall, humidity, suitable temperature and gentle wind. A crop variety to be grown for seed production in an area must be adopted to the photoperiodic and temperature conditions prevailing in that area, as for example the cole crops, cabbage, cauliflower, radish etc., are sensitive to photoperiodism and temperature for flower initiation and should be grown in a locality where low temperature prevails during short-day conditions. Regions of moderate rainfall and humidity are much more suitable for seed production than regions of high rainfall and humidity. Most vegetable crops require a sunny period and moderate temperature for flowering and pollination. High temperature during flowering causes desiccation of pollen resulting in poor seed set in wind-pollinated vegetable

crops. Bright sunny weather with gentle winds helps an even flow of pollen over the crop during flowering which is conducive to the best pollination and good seed set. However, very cold temperature may also damage seed quality especially in the early phase of seed maturation. In general, regions with extreme summer heat and very cold winters should be avoided for seed production, unless a particular crop is especially adapted to grow and produce under these conditions. It is, therefore, clearly evident that ample sunshine, relatively moderate rainfall and the presence of gentle winds have a decided advantage for high quality seed production and must be kept in view in the selection of areas for seed production.

Selection of variety

The selection of a right variety is very important for a successful seed production. The following aspects should be considered for the selection of variety for seed production:

(i) The vegetable variety to be grown for seed production must be genetically pure and adapted to the photoperiod and temperature prevailing in the production areas.
(ii) The variety should be a high yielder.
(iii) The variety should possess other desirable attributes. e.g., consumers' preference, disease and pest resistance etc.

Source of seeds

The seeds used for raising a seed crop should be of known purity, appropriate class and invariably obtained from authorized official agency. The following factors should be carefully examined while buying the seeds:

1. The seed is of appropriate class. For raising a foundation seed crop, seed of the breeder's seed class is required and for raising a certified seed crop, the seed of the foundation seed class is required for sowing.
2. The tag and seals of the breeder's seed/foundation seed bags purchased are intact.
3. The validity period has not expired.

Seed treatment

Seed treatment refers to the application of fungicide, insecticide or a combination of both to seeds so as to disinfect and disinfest them from seed-borne or soil-borne pathogens and storage insects. There are several presowing treatments which are used for vegetable seeds, including the application of pesticides for the control of seed-borne or soil-borne pathogens. The following types of seed treatments are followed for treating vegetable seeds:

Seed disinfection: This refers to the eradication of fungal spores that have established within the seed coat or in more deep seated tissues. For effective control, the fungicidal treatment must penetrate the seed in order to kill the fungus.

Seed disinfestation refers to the destruction of surface borne organisms that have contaminated the seed surface. Fungicides applied as dust, slurry or liquid have been found effective.

Seed protection: The purpose of seed protection is to protect the seed and

young seedlings from organisms in the soil which might otherwise cause decay of the seed before germination.

The range of vegetable seed treatments and their methods of application for the control of fungi, bacteria and insect-pests has been reviewed by various workers. The available treatments range from the application of chemicals to the seed as dusts or slurries to the application of heat via hot water, dry heat or steam air mixtures. Schedule for seed treatment of various vegetables is furnished in Table 18.

Table 18. Schedule for vegetable seed treatment

Crops	Name of chemical	Qty. of chemical for 1000 kg seeds(g)	Nature of application
Brinjal	Dimethyl dithiocarbamate 75 WDP	250	Dry dressing
Chillies	Captan 50 WDP	250	Dry dressing
Tomato	Dimethyl dithiocarbamate 75 WDP	335	Dry dressing
Cabbage, Cauliflower, Khol-khol	Dimethyl dithiocarbamate 75 WDP	85	Dry dressing
Cucurbits	Captan 50 WDP or	250	Dry dressing
	Dimethyl dithiocarbamate 75 WDP	250	Dry dressing
Beans, peas, Cowpeas	Captan 50 WDP or	125	Dry dressing
	Dimethyl dithiocarbamate 75 WDP	125	Dry dressing
Leafy Crops	Dimethyl dithiocarbamate 75 WDP	335	Dry dressing
Root andbulb crops	Dimethyl dithiocarbamate 75 WDP	250	Dry dressing
Okra	Captan 50 WDP or	100	Dry dressing
	Dimethyl dithiocarbamate 75 WDP	250	

Better agronomic management

In general, the principles and practices to establish the seed crop are the same as for the production of vegetables. But as the final objectives is to obtain seeds to be used for the production of further crop generations, it is important to apply best possible agronomic practices for raising the healthy seed crop. Timely seed sowing, optimum plant population and optimum irrigation are some of the agronomic practices that need to be taken into care for obtaining higher yield and better quality of seeds. The agronomic practices required for seed production may vary with the crop. The seed producer must have clear ideas about the agronomic practices of the concerned vegetable crop.

In the nutrition of seed crops, nitrogen, phosphorus, potassium and several other elements, e.g., boron, molybdenum, zinc, sulphur, etc., play an important role for the proper development of plant and seed. It is, therefore, advisable to know and identify the nutritional requirements of seed crops and apply adequate fertilizers. Optimum fertilization results in maximum yields, seed quality and better expression of plant type which facilitate roguing and thereby helps in

maintaining higher genetic purity as well.

Disease and insect pest management

Successful disease and insect control is very important in raising healthy seed crops. Pest infestation not only reduces the seed yield but also damages the quality. Generally the same control methods are used in seed production as for the production of market vegetables. The range of available pesticides differs from one country to another but only approved and proven products should be used in seed production, as possible adverse effects of pesticides include inadvertent killing of pollinating insects, modification of the seed's potential germination and a reduction in quality.

Supplementary pollination

Supplementary pollination using honey bees in hives in the seed fields of crops cross-pollinated by insects ensures good seed set and increases seed yields. Also hand pollination in cucurbit vegetables helps uniform seed setting, resulting in higher seed yield. Because cucurbits have separate male and female flowers, pollen transfer is needed for adequate fruit set. Providing bees for pollination, can greatly increase yields. Without good pollination, fruit set will be less and percentages of misshapen fruits will be higher. This results in less number of seeds in a fruit, resulting in low seed yield. Though historically, growers have relied on native bee populations to meet this need, losses of feral bees to disease have limited natural pollination. Bringing in 3–4 bee hives/ha during the first 3–4 weeks of flowering is recommended. The use of insecticides on the crop should be avoided at this time to prevent bee kill. However, if insecticide application is necessary, it should be done with care to avoid bee kill while bees are working the flowers. This means using less toxic compounds and spraying in the evening when bees are less active.

Harvesting of seeds

It is of great importance to harvest the seed crop at the time that will allow both the maximum yield and the best quality seeds. In general, the seeds are harvested when their moisture content is about 15–20%.

For best results seeds should be harvested at the right time, properly cleaned and dried (some seeds need to be 'fermented' before cleaning and drying) and then stored under conditions favorable to their long term health. Seed harvesting and cleaning techniques fall into two main categories according to whether the fruits and seeds are dry or wet when mature (actually, a third category exists of seeds which will die if dried out after maturing).

'Dry' seeds include beans, okra, peppers, and members of the onion and carrot families.Cleaning dry seeds usually involves simply drying and crumbling the pods or husks, then screening or 'winnowing' the seeds to separate them from the chaff.

'Wet' seeds are found in such plants as tomato, brinjal, melons, pumpkins and squashes. Cleaning wet seeds requires washing to clean the seeds and to separate them from the surrounding pulp. In addition, in some cases wet seeds (such as tomato) are best fermented for several days to remove germination inhibiting

substances from the seed coats. Fermenting can also help such seeds as members of the Cucurbitaceae family by killing molds, mildews and other disease organisms that may be present on the seeds after growing.

Some families (such as the Cucurbitaceae family) include some plants that produce wet seeds (e.g., pumpkins, squashes and melons) and others that produce dry seeds (e.g., luffa and hard gourds).

Cleaning of dry seeds: Harvest dry seeds from their plants when their pods or husks have dried. Some seeds can be picked before they are fully dried on the plants if rains threaten. Other plants, however, (i.e. Brassicaceae family), will not finish ripening once they have been removed from the plant. Leaving seeds on the parent plant to full maturity and dryness is always preferable.

Once pods or husks have been harvested, store them in a dry place and wait until they are thoroughly dry. When the pods or husks are dry enough they will easily crumble between our hands. Crumble the pods or husks until all the seeds are released. Then place seeds and chaff in a bowl or box and swirl or shake gently. Most of the larger chaff pieces will rise to the top and can simply be removed by hand.

Seeds and finer chaff are easy to separate by a variety of methods. One way is to use two screens of varying mesh, one a little smaller than the seeds and the other a little larger. The first screen lets anything smaller than the seeds fall through, and the second lets the seeds through and stops anything larger.

A very ancient method of cleaning seeds is called 'winnowing.' In a gentle wind, drop the seed/chaff mixture from a height of several feet into a bucket or onto a sheet or tarp. With a little skill and some cooperation from the wind (a fan in an enclosed space can be used for better control), seeds will fall into the bucket or onto the tarp while chaff blows away to one side.

Another, very simple way to winnow small quantities of seeds is to swirl or gently bounce the seeds and their chaff in a shallow bowl while carefully blowing chaff away with your breath. It's a good idea to do this over a cloth or newspaper to catch seeds blown out of the bowl with the chaff. These can then be hand cleaned.

Cleaning of wet seeds: Wet seeds are easy to clean, though some need the additional step of fermentation. Seeds which require fermentation should be cleaned after fermenting, not before fermenting.

Allow the fruits to fully mature on their plants before harvesting. To clean wet seeds, scoop the seeds from the fruit, pulp. Pour the seeds and pulp into a large, sloping bowl and add water. Healthy seeds will sink to the bottom of the bowl, while dead seeds and most of the pulp will float. Use fingers to gently separate all the seeds from the pulp. Then, to remove the pulp and dead seeds, carefully pour the extra water with the floating pulp and dead seeds from the bowl. Pour quickly enough for dead seeds and pulp to pour off the top, and slowly enough so that the heavier, good seeds remain safely on the bottom. By repeating this rinsing and pouring process several times, the seeds can be gotten very clean.

To initially dry seeds after cleaning, drain them of excess moisture in a strainer. Pat the bottom of the strainer with a cloth towel to pull extra water from the seeds after they have drained. Then spread the seeds on a piece of a shiny ceramic plate

to dry (they will stick to paper, even waxed paper). Place the ceramic plate in a cool, dry shady spot for several days.

After the seeds are dry, they can be carefully removed from the plate and finally dried before being stored.

Advantages of fermenting wet seeds: Fermenting some wet seeds can dramatically improve their ability to sprout. Fermentation removes germination-inhibiting substances from seed coats, makes them more permeable to water, and also helps reduce or control seed borne diseases (for healthier seedlings). Fermentation is needed for tomato seeds (in order to remove a germination inhibiting gel), and can also benefit melon, cucumber, brinjal seeds, though more care must be taken with these to avoid premature sprouting. Ferment Cucurbitaceae family seeds for only a day and a half or so, brinjal a little longer.

How to ferment seeds: To prepare seeds for fermenting, simply squeeze or scoop the seeds together with the pulp that surrounds them into a plastic drum/ bucket with a little water (about half as much water as seeds and pulp). There is no need to include more pulp than naturally comes with the seeds. Store this seed and pulp mixture in a warm place (25–30° C) for 1–5 days (depending on the seed type and whether conditions are warmer or cooler).

Fermentation will be evidenced by bubbling and/or by the formation of a white mold on the surface of the mixture. As soon as the bubbling or mold have been evident for a day or so, pour the mix into a bowl and clean.

Watch closely, as seeds left fermenting too long (especially above 30° C or so) may germinate, ruining their chances for storage. Once the seeds start to ‘imbibe’ or swell due to taking on water, they will have begun their internal process of germination. By the time their tiny roots have begun to emerge, it is far too late to try and dry them for storage.

Brinjal and pumpkin/squash seeds germinate more readily than tomato, so they should only be fermented for a day or so. Squash seeds, particularly, are quick to germinate—sometimes even sprouting in well ripened squashes while they are still on the vine. It is not required to ferment pumpkin/squash or brinjal seeds, though it increases their germination rates and kills some seed borne diseases. In general, when temperatures are kept between 25 and 30° C or so, fermenting is safe and beneficial and will be safely completed before seeds begin the process of germination.

Drying and storage of seeds

After extraction, seeds are cleaned and dried. In order to preserve seed viability and vigour it is necessary to dry seeds to safe moisture content level. The drying of seeds may be done by sunlight, chemical desiccants and by mechanical driers.

The air temperature of the drier should not exceed 38°C in order to maintain good vigour and viability of the seeds. Sensitive seeds like onion, carrot, leek, etc., require drying temperature below 27°C. For short period storage clean and dried seeds should be filled in neat and clean sacks or bags and stored in a clean, cool godown. •

CHAPTER 13

Solanaceous Vegetables

THE term 'solanaceous vegetables' generally refers to plants in the nightshade family, Solanaceae, commonly called as 'brinjal family'. It includes about 90 genera and 2,000 species. Members of this family have a cosmopolitan distribution. There are around 60 species found in India. The common examples of edible species are, *Solanum tuberosum* (potato), *Solanum melongena* (brinjal), *Solanum lycopersicum* (tomato), and *Capsicum annuum* (chilli and sweet pepper). When referring to fruiting vegetables, all of the above except potato, a tuber crop, are included. Their cultural requirements have many things in common

TOMATO

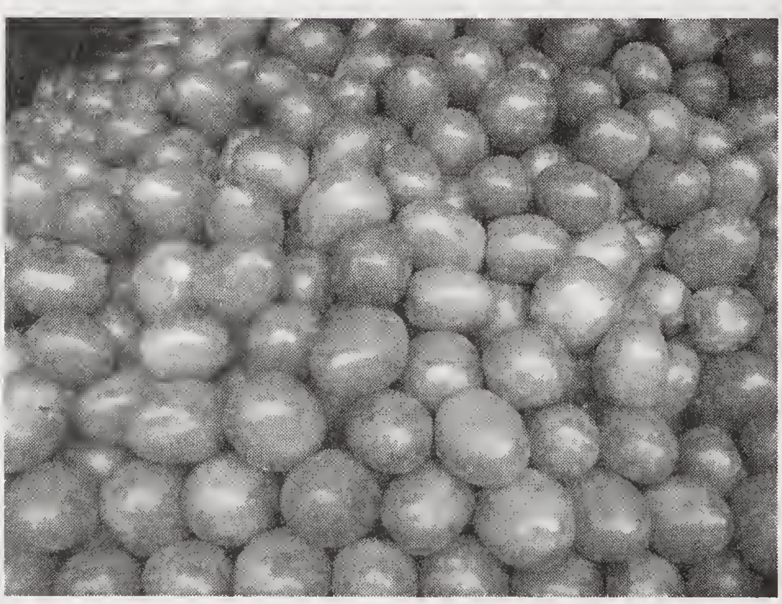

Fig 1. Tomatoes

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown nutritious vegetable in the world. Cultivated tomato is generally accepted to have originated in the tropical America since all related species of tomato are native to the Andean region and from where it spread to other parts of the world in the 16th century and became popular in India within the last 9 decades. In England, it was popularly known as 'love apple'. The word tomato not used until 1695 is said to be derived from the xitomate or xitotomate. In Hindi it is known as *tamatar,* and *vilayati baingan.*

Tomato is one of the most widely grown vegetable crops in India. It is grown across the country as a common vegetable in farm gardens, home gardens, market gardens for fresh consumption and for processing purposes. In India it is grown in an area of 907,000 ha with a production of 18653,000 tonne and productivity of 20.6 tonne/ha. The major tomato: producing states are Bihar, Karnataka, Uttar Pradesh, Odisha, Andhra Pradesh, Maharashtra, Madhya Pradesh, Asom and West Bengal (NHB, 2011).

Tomato is used as a cooked vegetable, commonly with other vegetables in curry, consumed raw or is made into soups, salads, preserves, pickles, *chutneys*,

ketchups, sauces and many other products. Tomato is a good source of vitamins, viz. ascorbic acid or vitamin C_1, vitamin A, thiamine or vitamin B_1 and riboflavin or vitamin B_2 in that order. A 100 g edible portion of tomato contains 94.1 g water, 1 g protein, 0.3 g fat, 4 g carbohydrates, 1,100 IU vitamin A, 0.2 mg vitamin B, 0.6 mg nicotinic acid, 0.31 mg pantothenic acid, 23 mg vitamin C, 0.27 mg vitamin E, 390 mg citric acid, 268 mg potassium 27 mg phosphorus, and 51 mg chlorine (Nath *et al.* 2002).

Botany

Tomato (*Solanum lycopersicum* L.; Syn. *Lycopersicon esculentum* Mill.) belongs to the family Solanaceae and genus *Solanum.* It is a herbaceous annual plant with bisexual flowers and the fruit is a true berry. It is a self-pollinated crop but cross-pollination up to 5% has been reported. In tropical South America where it is native, tomato is a perennial crop. It is usually grown as an annual for both fruit as well as seed purpose. According to the growth habit, the tomato plants have been categorized into two types, viz. (i) indeterminate and (ii) determinate.

The plant of indeterminate type terminates in a vegetative bud and the main axis continues growing indefinitely, whereas that of the determinate type terminates in a flower bud and is appropriately called 'self topping' or 'self pruning' type. Many varieties of determinate type tomato plants do not have adequate foliage to protect their fruit. Some of them fruit very early. The determinate varieties can be harvested in 2–3 harvests, while the fruiting period of indeterminate type is prolonged. Tomato is a true diploid with 2n=24 and all the species of *Solanum* have 2n=24 (Peter, 1998; Rashid and Singh, 2000).

Floral biology and pollination: Tomato inflorescence or flower cluster is borne laterally in small-forked raceme cyme. The number of flowers per cluster in most cultivars varies from 4 to 5 and sometimes more. In most commonly grown field varieties about 2–4 flowers set fruits within each cluster. Tomato flower has a 5–10 parted calyx which persists until fruit matures. The yellow petals are united in a short tube with five or more lobes which are often recurved. The five stamens are attached to the base of the corolla tube. The long anthers are partly united in the form of a cone surrounding the pistil. The latter consists of a multicelled ovary and a long slender style reaching the tip or projecting from the staminal cone as much as 2 mm with a capitate, single narrow or somewhat bulbous stigma. The buds, flowers, and fruits develop progressively within an individual cluster. There is no definite flowering peak in tomatoes. Anthesis appears to be correlated with temperature and soil moisture. Tomato is normally self-pollinated crop. Self-fertilization being favoured by the position of the receptive stigma within the cone of anthers and the normal pendant position of the flower. Though the stigma is receptive at the time of anthesis, anthers do not dehisce until about 24–48 hr later. Cross-pollination of tomato flowers to the extent of about 5% may occur through insects (Rashid and Singh, 2000).

Breeding

Initially most of the important varieties were introduced from the western countries and some of them became popular among the growers and consumers

in different agro-climatic regions depending on their adaptability. The Indian Agricultural Research Institute (IARI), New Delhi, has introduced important tomato varieties from all over the world which were evaluated during early sixties of the last century for various purposes. Some of the introduced American varieties like 'Sioux', 'Marglobe' etc. were recommended for commercial production. A significant achievement was made at the IARI, New Delhi, when the new tomato variety 'Pusa Ruby' was developed by crossing 'Sioux' (a good-quality American variety) with 'Improved Meeruti' an indigenous hardy variety. The new tomato varieties 'Arka Saurabh' and 'Arka Vikas' from Indian Institute of Horticultural Research (IIHR), Bengaluru; 'Co-3' from TNAU, Coimbatore; 'Punjab Chhuhara' and 'Punjab Kesari' from PAU, Ludhiana, 'HS 101' 'HS 102' from Kalianpur, 'AC-238' and 'Plant T-3' from Pantnagar, and 'Sweet -72' from RARI, Gwalior, were promising besides some old varieties like 'Pusa Ruby', 'Pusa Eraly Dwarf' 'Sioux', 'Roma' and "La Bonita'. The varieties 'Roma', 'La Bonita' and 'Dwarf Money Maker' held promise for commercial cultivation in different regions of our country in view of their higher yield and better fruit quality, till late 80s and early 90s of the last century (Nath *et a*l. 2002).

There are some determinate and indeterminate types in tomato. The determinate varieties are 'Pusa Ruby', 'Sioux', 'Pant Bahar' (AC 234), 'Arka Vikas', 'Arka Saurabh', 'Pant T 3 '(AC 238), 'Dt 10', 'Bt 12'. Hybrids and indeterminate varieties are 'AARTH 3', 'Pusa Hybrid 2', 'NA 501' and 'DTH 4' and 'ARTH 4', 'MTH 6', 'FMH 2'('Arka Vardan'), 'KT 4', 'NATH 601', 'FMH 1', 'BSS 20'. Heterosis breeding is common in tomato to develop F_1 hybrids. It is important to note here that till late 80s and early 90s the breeding objective was for higher yield. With the changing agro-climate and crop growing situations, changing pest scenario and value-added consumer preference during the middle of the nineties of the last century onwards, additional objectives like breeding for insect pest resistance, breeding for abiotic stress (heat and moisture stress) resistance, breeding for processing qualities, etc., were added along with breeding for higher yields.

Work is in progress under National Agricultural Research System of the country with regard to fruit yield, appearance, plant parameters, resistance to diseases and pests, salt and drought tolerance etc. Several F_1 hybrids from private companies and research centers have recently come up and they are now gaining popularity due to their high yield potential. Some of them are reported to be resistant to diseases and pests, apart from good quality for fresh consumption and processing.

Improved cultivars of tomato

Disease resistant cultivars

Punjab Varkha Bahar 1: It has determinate plants with dense cover of dark foliage and is developed by PAU, Ludhiana. It produces round, dark red and firm fruits. The variety takes 90 days from the date of transplanting to maturity. The variety is resistant to tomato leaf curl virus and produces a yield of 538 q/ha.

Punjab Varkha Bahar 2: It has semi-determinate plants with dense light green foliage cover and is developed by PAU, Ludhiana. It produces round dark red fruits of medium firmness. It takes 100 days from the date of transplanting for

attaining maturity. This tomato leaf curl virus resistant variety yields on an average 541 q/ha.

Kashi Vishesh: It has determinate plants and fruits are spherical and is developed by IIVR, Varanasi. It is recommended for Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Bihar, Uttarkhand, Punjab, Jharkhand, Chattisgarh, Odisha and southern states. It is resistant to TLCV. Duration 70–75 days after transplanting yield: 450–550 q/ha.

Arka Abha: Developed by IIHR, Bengaluru. Plants semi determinate, fruits oblate with average weight 75 g. Resistant to bacterial wilt caused by *Ralstonia solanacearum* suitable for *kharif* and *rabi*. Duration 140 days and yield 430 q/ha.

Arka Alok: Developed by IIHR, Bengaluru. Plants determinate, fruits firm, resistant to bacterial wilt. Both for *kharif* and *rabi* duration 130 days, yield 400 q/ha.

Swarna Naveen: Released by ICAR-RCER, Patna. Resistant to bacterial wilt. Yield: 600–650 q/ha.

Swarna Lalima: Released by ICAR-RCER, Patna. Resistant to bacterial wilt. Yield: 600–700 q/ha.

Arka Abhijit: This is an F_1 hybrid developed by IIHR, Bengaluru. For Karnataka, Maharashtra and Madhya Pradesh. Plants semi-determinate, dark green leaves, fruits medium [65–70 g], suitable for fresh market, resistant to bacterial wilt. Duration 140 days and yield 650 q/ha.

Arka Shreshta: This is an F_1 hybrid developed by IIHR, Bengaluru. Plants semi-determinate fruits medium large. For fresh market and processing. Resistant to bacterial wilt and suitable for *rabi*. Yield 760 q/ha. Duration 140 days. Recommended For Karnataka.

Arka Swaraksha: This is an F_1 hybrid developed by IIHR, Bengaluru. Plants semi-determinate fruits medium large. For fresh market and processing. Resistant to bacterial wilt and suitable for *rabi*. Yield 760 q/ha. Duration 140 days. Recommended for Karnataka.

Arka Samrat (H-240): This is a hybrid developed by IIHR, Bengaluru. High yielding F_1 hybrid with triple disease resistance to tomato leaf curl virus (ToLCV) + Bacterial wilt (BW) + early blight (EB). Plants, semi-determinate with food foliar cover. Fruits high round, firm with average fruit weight 100–110 g. Yield: 800–850 q/ha in 140 days.

Arka Rakshak (H-241): This is a hybrid developed by IIHR, Bengaluru. High yielding F_1 hybrid with triple disease resistance to ToLCV+BW+EB. Plants, semi-determinate with good foliar cover. Fruits square round, very firm with average fruit weight 80–90 g. Yield: 750–800 q/ha in 140 days.

Arka Ananya: This is an F_1 hybrid developed by IIHR, Bengaluru. This has combined resistance to ToLCV and Bacterial wilt. It it gives an yield of 760 q/ha. Fruits are round, firm (5.0 kg/cm^2), medium (50–60 g) with light green shoulder. First fruit maturity in 55–60 days. It develops deep red colour on ripening.

Swarna Sampada (F_1): Released by ICAR-RCER, Patna. Resistant to bacterial wilt and early blight. Yield: 1,000–1,050 q/ha.

Arka Ashish: Developed by IIHR, Bengaluru. Plants determinate with dark

green foliage, fruits oval, excellent fruit colour [lycopene 10 mg/100 g] with TSS 4.8%. Suitable for processing. Tolerant to powdery mildew and fruit cracking. For both *kharif* and *rabi*. Duration 130 days and yield 380 q/ha.

Root knot nematode resistant cultivars

Pusa hybrid-2: Developed by IARI, New Delhi. Determinate, compact plant type, good foliage cover, fruits round to flattish round, firm, smooth, attractive, develop uniform red colour on maturity, tolerant to root knot nematodes. Maturity 110–120 days. Yield 591 q/ha

Pusa hybrid -4: Developed by IARI, New Delhi. Determinate, compact plants, dark green foliage, prolific are bearing, highly tolerant to root knot nematodes. Fruits attractive, round, smooth, medium sized thick pericarp and uniform ripening. Maturity 120 days. Yield 600 q/ha.

Arka Vardan: This is an F_1 hybrid developed by IIHR, Bengaluru. Plants indeterminate, fruits large [140 g] and round tolerant to fruit cracking. Resistant to nematodes. Requires staking. For both *kharif* and *rabi*, 160 days duration and yield 750 q/ha

Pusa 120 (SL 120): This variety was released by IARI, New Delhi. Semi-determinate, prolific bearer, medium coverage, medium to large-sized, flattish round fruits, uniform ripening, circular cracking, highly tolerant to nematodes. Maturity 130 days. Yield 300–350 q/ha.

Cultivars suitable for processing

Arka Ashish: Developed by IIHR, Bengaluru. Plants determinate with dark green foliage, fruits oval, excellent fruit colour [lycopene 10 mg/100 g] with TSS 4.8%. Suitable for processing. Tolerant to powdery mildew and fruit cracking. For both *kharif* and *rabi*. Duration 130 days and yield 380 q/ha.

Arka Saurabh: Developed by IIHR, Bengaluru. High-yielding, (40 tonne/ha). It is semi-determinate, fruits very firm and round, medium sized with smooth skin and thick flesh. Very good keeping quality and suitable transport. 8–10 days in room temperature amongst the round fruited varieties. TSS 3.9% and acidity 0.39%, suitable both for fresh consumption and processing.

Pant T-3: Developed by GBPUAT, Pantnagar. Semi-determinate, dark green foliage, fruits round, smooth, medium size, suitable for processing. Maturity 70 days. Yield 190 q/ha.

Pusa Gaurav: Developed by IARI, New Delhi. Determinate, good foliage cover, firm fruits, oval in shape (egg shaped), yellow stem end, uniform ripening, thick pericarp, two locules, highly suitable for long distance transportation and processing. Maturity 110 days. Yield 300–400 q/ha.

Punjab Chhurhara: Developed by PAU, Ludhiana. Determinate, high yielding, elongated fruits, pear-shaped fruits with medium size, low in juice content, suitable for processing and transportation. Maturity 100–110 days. Yield 325 q/ha.

Arka Ahuti: Developed by IIHR, Bengaluru. Plants semi-determinate, Fruits oblong, TSS 5.2%. Suitable for processing for both the seasons, 140 days and yield 420 q/ha.

Cultivars suitable for transportation

Pusa Hybrid-8: Developed by IARI, New Delhi. Determinate, fruits round, smooth, medium-sized thick pericarp, suitable for long distance transportation. Maturity 105 days. Yield 557 q/ha (main season).

Pusa Divya (F_1 hybrid): Developed by IARI, New Delhi. Indeterminate fruits round, smooth, firm, suitable for long distance transportation. The only hybrid developed so far by utilizing male sterile line in India. Maturity 90–100 days. Yield 350–450 q/ha.

Swarna Baibhav (F_1): Released by ICAR-RCER, Patna. Suitable for long distance transportation and processing. Yield: 900–1000 q/ha.

Pusa Rohini: Developed by IARI, New Delhi. Determinate, fruits round, smooth medium-sized thick pericarp. Suitable for long distance transportation. Maturity 120 days. Yield 410 q/ha.

Roma: Introduced by IARI, Katrain. Determinate plants, light green broad leaflets, medium sized fruits, elliptical with yellow stem end, suitable for transportation and hilly areas. Maturity 100–120 days. Yield 300–350 q/ha.

Italian Red Pear: Introduced by IARI, New Delhi. Determinate, green stem end, green foliage, fruits elliptical, neck formation. Suitable for transportation. Maturity 90–110 days. Yield 200–300 q/ha.

Cultivar suitable for rainfed cultivation

Arka Meghali: Developed by IIHR, Bengaluru. Plants semi-determinate, narrow dark leaves, fruits medium, oblate and deep red. Suitable for rainfed cultivation and *kharif* season. Duration 125 days and yield 180 q/ha.

Cultivars suitable for low to high night temperatures

Pusa hybrid-1: Developed by IARI, New Delhi. Determinate, good foliage colour, fruits round, smooth, attractive. Can set fruit upto 28° C night temperature, fruits from June to mid-July, the lean period for tomato in north India. Maturity 95 days. Yield 320 q/ha.

Pusa Sadabahar: Developed by IARI, New Delhi. Determinate, dwarf, accommodate more plants per unit area, prolific bearer, smooth, oval to round, attractive fruits. Highly suitable for growing under wide range (8–30 °C) of night temperatures. Maturity 60 days. Yield 300–400 q/ha.

Pusa Sheetal: Developed by IARI, New Delhi. Semi-determinate, light green foliage, fruits flattish round, medium size, attractive, uniform ripening, yellow stem end, prolific bearer, capable of fruit setting at 8° C night temperature. Maturity 90 days. Yield 360 q/ha.

Cultivar with longer shelf-life

Kashi Sharad: Developed by IIVR, Varanasi. Plants indeterminate with broad leaves fruits are slightly oval, firm and suitable for longer shelf life. Average Yield 400–500q/ha. Suitable for Jammu and Kashmir, Himachal Pradesh and Uttarakhand.

Other cultivars

Pusa Ruby: Developed by IARI, New Delhi. Indeterminate, light green foliage,

fruits flat, slightly furrowed, yellow stem end, attractive uniform ripening, slightly acidic in taste. Maturity 60–85 days after transplanting. Yield 300 q/ha.

Pusa Early Dwarf: Developed by IARI, New Delhi. Determinate, good foliage cover, fruit medium in size, slightly furrowed, flattish round, yellow stem end, very prolific bearer. Maturity 70–80 days. Yield 300 q/ha.

Pusa Uphar: Developed by IARI, New Delhi. Indeterminate, upright plant, leaves cut, moderate coverage, fruits smooth, round to flattish-round, medium-sized, yellow stem end, thick pericarp. Maturity 120 days. Yield 370 q/ha.

S-12: Round fruited variety developed by irradiation by PAU, Ludhiana. Determinate, bushy plants, fruits round, medium-sized uniform red at maturity, jucy, highly acidic. Maturity 90–110 days. Yield 175–280 q/ha.

Kashi Amrit: Developed by IIVR, Varanasi. Plants determinate, fruits large, flattish round and red. Duration 75–80 days and yield 500–600 q/ha. Suitable for Rajasthan, Gujarat, Haryana and Delhi.

Kashi Hemant: Developed by IIVR, Varanasi. For Madhya Pradesh, Chattisgarh, Andhra Pradesh, Odisha, Maharashtra. Yield 400–420 q/ha.

Arka Vikas: Developed by IIHR, Bengaluru. It is a high-yielding variety (350–400 q/ha) with large-sized, oblate, medium-sized firm fruits. It is suitable for fresh market.

Arka Vishal: Developed by IIHR, Bengaluru. Plants indeterminate, fruits large [140 g] tolerant to cracking, requires staking, suitable for *kharif* and *rabi*. Duration 165 days and yield 750 q/ha. Recommended for Karnataka, Bihar and Uttar Pradesh.

Co-1: Developed by TNAU, Coimbatore. The plant is dwarf, semi-spreading habit with dark green foliage. The fruits are round and smooth, pale green when unripe and red when fully ripe. The fruits are borne in clusters of 6 to 8, each weighing about 125 g. It yields an average of 380 q/ha.

Sweet-72: It is a cross between 'Pusa Red Plum' and 'Sioux'. It bears round, scarlet red, sweet fruits. Yield is 200 q/ha. Developed at the Regional Agricultural Research Institute, Gwalior, Madhya Pradesh.

Climate and soil

Tomato is a warm season crop. It is sensitive to frost and it does not thrive at low, non-freezing temperatures. High temperatures, accompanied by low humidity and dry winds, frequently damage floral parts and there will be no fruit set. It is reported that tomato pollen grains germinate best at 29.4°C, germinate poorly at 10°C and very poorly at 37.3°C. Thus both high and low temperatures interfere with the setting of fruits. Tomato plants withstand drought fairly well but fruits are subject to blossom end rot and the fruits crack if moisture supply follows drought. It cannot be grown successfully in regions of higher rainfall due to possible damage by diseases. High rainfall eventually lead to higher incidence of foliar and fruit rot diseases. With rise in temperature, there will be rise in insect vector population, which leads to increased incidence of viral diseases like tospo and TLCV. In the southern tropics of the country, wherever moderate climate is present, tomato is grown throughout the year. However, October-November transplanting can produce best yield and quality.

Tomato grows on practically all soils, from light sandy to heavy clay. Light soils are good for an early crop, while clay loam and silt loam soils are suited for heavy yields. If the soil is acidic, liming is advocated, as tomatoes do best in a soil that has a *p*H of 6–7.

Cultural requirements

Planting time: Usually two successful crops are taken in the northern plains where frost occurs during winter, whereas in frost-free areas where winter is not severe three crops in a year are possible. In regions where frost occurs, the first crop is transplanted in February after the frost is over and the second crop is transplanted in July when the monsoon sets in. In the southern plains the first crop is transplanted in December–January, the second crop in June-July and the third crop in September-October, depending on the availability of irrigation facilities.

The crops sown in January-February and June-July are susceptible to leaf curl virus. An early planting can avoid the incidence of the disease. Hence, dates of sowing can be adjusted according to the prevailing conditions. In hills, the seed sowing depends on the elevation of the place. On lower hills, the seeds are sown in February-March, while at higher altitudes it can be done in March-April.

Nursery raising and seed rate: Tomato seedlings are raised in the raised nursery beds. Seeds are sown in line on a well-prepared seedbed and lightly covered with soil. The seedbeds should be irrigated immediately after sowing. The seedlings should be protected from strong sun and heavy rains. When the plants are about four-week-old and 12–15 cm in height, they are transplanted. Good tomato seeds remain viable for about four years and the germination is about 85–90%. The seed rate per hectare for hybrids in raised bed method is 100–125 g and for OP varieties is 200–250 g.

Seedling raising using seedling trays and cocopeat as media in a protected structure such as nethouse is the order of the day. This ensures quality seedlings with less viral disease infection to the seedlings. Many enterprising fanners have started vegetable nursery business in the intensively vegetable growing areas and farmer can directly buy seedlings from these seedling units. However, individual farmers can also raise seedlings using this improved method. A net cage made of 40-mesh nylon cloth, steam sterilized cocopeat and 98-celled seedling trays need to be procured. To produce 10,000 seedlings, a net cage of the size 7.5 m length, 3.4 m width and 2.4 m height is to be made. In each cell seed is dibbled and seedlings raised. About 75–100 g seed is required in portray method to raise seedlings required for planting 1 ha (spacing of 120 cm × 45 cm).

Land preparation and spacing: Good land preparation is essential to express the potential of the crop. This can be achieved by cultivation to a depth of 30–45 cm by ploughing, clod crushing, and rotavating. Before the final land preparation, about 25 tonne/ha of well decomposed farmyard manure is added.

Layout the land into raised bed system by making a bed of 80 cm width and furrow of 40 cm width, i.e. furrows are opened at a spacing of 120 cm. Seedlings

are planted in the center of the bed at a spacing of 45 cm from plant to plant. Broad bed system of cultivation facilitates the adoption of improved technologies like drip irrigation, fertigation, and polyethylene mulching.

In the normal method of transplanting, ridges and furrows are opened at a spacing of 60–75 cm. The planting distance within a row is kept at 30 cm for determinate varieties and 60 cm for indeterminate varieties.

Manure and fertilizers: The fertilizer recommendation for a hybrid tomato is 25 tonne farmyard manure, 180 kg N, 120 kg P, and 150 kg K/ha. 1/3 Nitrogen, full Phosphorus and 1/3 Potash is to be applied before transplanting as basal dose. 1/3 Nitrogen and 1/3 Potash need to be side dressed 4 weeks after transplanting. Remaining 1/3 Nitrogen and 1/3 Potash need to be side dressed 8–9 weeks after transplanting (IIHR, 2010)

For open pollinated varieties the recommended dose of fertilizers is 25 tonne farmyard manure, 120 kg N, 100 kg P and 60 kg K/ha. Half the dose of nitrogen is applied as basal dose and remaining half is given after 4 weeks of transplanting. Entire phosphorus and potash is applied as basal dose before transplanting (IIHR, 2010).

Generally, the complete doses of farmyard manure, phosphate and potassic fertilizers are applied at the time of field preparation for transplanting the seedlings. The fertilizers are placed in bands, 7.5–10 cm deep on both sides of the row before making furrows.

For southern and western region requirement is 100 kg N, 80 kg P, and 50 kg K/ha or 100–120 kg N, 60–80 kg P and 100–120 kg K/ha (Swarup, 2006).

For Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Bihar and West Bengal, the requirement is 150 kg N, 60 kg P and 60 kg K/ha. The hybrid varieties have higher requirements, i.e. 200 kg N, 100 kg P and 100 kg K/ha.

The amount of fertilizers to be added depends on the variety and soil. A crop grown in spring- summer, require less N when compared with grown in winter. Late maturing varieties require more nitrogen. In general, the crop requires 80–120 kg N, 50–80 kg P and 50–60 kg K/ha.

Transplanting: Systemic insecticide need to be sprayed before transplanting the seedlings in the tray. Similarly fungicides like copper oxychloride 50 WP (0.3%) need to be drenched to the seedlings to prevent the soil-borne disease immediately after transplanting.

In the raised bed method of planting, 25-day-old hardened and stocky seedlings are planted in the center of the bed at a spacing of 45 cm from plant to plant. Controlled irrigation is to be provided till one week to minimize the seedling mortality soon after transplanting.

In the normal method of transplanting, ridges and furrows are opened at a spacing of 60–75 cm. The planting distance within a row is kept at 30 cm for determinate varieties and 60 cm for indeterminate varieties.

Planting should be done in the late afternoon followed by light irrigation. Seedlings are transplanted in small flat beds in light soils where irrigation is available, and on shoulders of furrows where irrigation water is scanty. In heavy soils seedlings are usually transplanted on ridges and during the rains it is advantageous to plant the seedlings on ridges.

Inter-cultural operations

Irrigation: Tomato needs very careful irrigation which should be sufficient in right time but waterlogging should be avoided at all times during the crop growth. Quality of fruits improves by optimum moisture supply during flowering and fruit setting. Heavy irrigation after a long dry spell may result in fruit cracking. Similarly, providing irrigation late in the season may result in watery fruits of poor quality. However, irrigation should be given according to the local need.

Irrigation should be done regularly so that the soil remains moderately moist. Excessive irrigation induces the plant to vine and dropping off of the blossoms. During summer, irrigation at every 3–4 days interval may be necessary, whereas in winter, at 10–15 days interval is sufficient.

Weeding: Weeding and hoeing should be done at regular intervals so as to keep the field free of weeds and to help soil aeration and proper root development. As the plants grow, the inter-cultural operation should be shallow so that the damage to the roots, which are present 5 cm below the soil, be avoided.

Top dressing and earthing up: Top dressing with remaining quantity of fertilizers is to be done as mentioned earlier. In the ridges and furrows method of planting, earthing up of plants is to be done.

Training, pruning and staking: Arrangement for staking the tomato plants is to be made by using bamboo, casurina or eucalyptus sticks and GI wire. Staking helps in better plant-protection, easy harvesting and finally improves the yield and quality. Training of tomato plants with the help of wires or ropes is claimed to result in early ripening, higher yield of better quality fruits and seeds, lesser disease incidence, easier inter-cultural operation and harvesting. Pruning side shoots and staking have claimed to have higher yield, uniform and larger fruits. Staking of tomato plants has proved to be beneficial. In indeterminate varieties the yield and quality have improved and more so in rainy and winter, where the incidence of some of the diseases of fruit and foliage is also reduced.

Mulching: Polyethylene mulch of 30 thickness with silver-black surface is to be used. For beds of 80 cm width, 100 cm wide polyethylene mulch film need to be covered by tightly stretching the film and securing the edges of the sheet by burying in the soil.

Drip irrigation: Wherever it is possible, adoption of drip irrigation and fertigation in tomato is beneficial in many ways in tomato cultivation. A head control unit having pump, disc filter, fertilizer injecting ventury or tank or pump, pressure gauge and air release valve are necessary. Inline drip lateral are taken out from the PVC pipe at a distance of 1.2 m. These inline drip lateral with an emitting spacing of 40 cm having discharge rate of 3–4 liters/hr is selected. Daily drip irrigation is to be followed based on the stage of the crop (crop factor) and daily evaporation. The crop factor varies between 0.3 during establishment to 0.80–0.85 during peak growth and flowering period at about 50 to 60 days after transplanting. It is advisable to check the water quality parameters such as EC before the installation of drip irrigation.

Pest and disease management

Diseases

Damping-off (Rhizotonia* sp., *Phytophthora* sp., *Pythium* sp. or *Pellicularia* sp.*): The stem of the seedling decays at the soil surface and finally it collapses due to shrinking of tissues of the stem near the ground. The disease may be controlled by sterilization of the nursery soil by steam or formalin and by treating the seeds with captan 50 WP (0.2%). The nursery should also be drenched with captan 50 WP (0.2%) after germination of seeds if disease is seen.

Fusarium wilt (Causal organism Fusarium* sp.*): The lower leaves of plants become yellow, wilt and die and the diseased plants remain stunted. It may be controlled by (*a*) using seed from healthy plants, (*b*) rotating crops to decrease the fungus population, and (*c*) growing resistant varieties like 'Marglobe'.

Bacterial wilt (Causal organism Pseudomonas solanacearum): In this case, there is a sudden wilting of plants which do not recover at all. The disease is known to be soil borne. It is difficult to control the disease. The only solution seems to be to grow resistant varieties such as, 'Arka Abha', 'Atka Alok', 'Arka Ananya' and 'NS-501', 'Shakthi', 'BT-1' and 'BT-10'.

Early blight (Causal organism Aternaria solani): Dark brown to black spots with concentric rings are formed on leaves and stems and dark decayed spots on the ripe fruits. The crop should be sprayed with ziram 80 WP (0.2%). This spray may be repeated after 10–15 days interval. The seeds from infected plants may not be used and the clean seeds may be treated with captan 50 WP (0.2%) as in the case of damping off disease to avoid infection, if any. A proper crop rotation should be followed avoiding solanaceous crops.

Fruit rot (Causal organism Phytophthora lycopersici): Brownish spots appear on fruits at the point of contact between the fruit and the soil. The fruit decays and becomes unmarketable. The disease is effectively controlled by spraying mancozeb 75 WP (0.2%) or copper oxychloride 50 WP (0.3%) and the spray may be repeated after 15 days in high rainfall areas. To reduce the infection, the plant should be staked and the drainage system should be improved.

Powdery mildew (Causal organism Oidium* sp.*): The vegetative parts are damaged by the appearance of white mealy growth which ultimately leads to defoliation. It may be reduced by the application of sulphur 85 WP (0.2%) at 10–15 days intervals.

Septoria leaf spot: Symptoms of the disease are small, circular, water soaked spots that later get dark margins and a grey to yellow centre. In the later stage the leaves dry up and drop off. The disease may be effectively controlled by spraying zineb 75 WP (0.2%) or copper oxychloride 50 WP (0.3%) at 7–10 days intervals.

Tomato leaf curl virus (TLCV): It is the most serious disease of tomato especially during summer in the northern plains. The symptoms are size reduction, puckering and curling of the leaves and stunted growth of the plants. The disease is spread by white fly. One of the ways to reduce the infection has been to uproot the infected plants around the field. Efforts may also be made to reduce the white fly population by the spray of imidacloprid @ 0.4 ml/litre or thiomethoxam 25 WP @ 0.3 g/litre. The fruit may be harvested before spray of insecticides or after

5–6 days of spray. TLCV resistant varieties/hybrids such as, Arka Ananya, Hissar Anmol, Sankranthi, Nandi and Vybhav may be cultivated.

Tobacco mosaic virus (TMV): The virus is highly infectious and spreads even through the hands of the workers engaged in various cultural operations in the field. It is a very serious disease in the northern plains though present in other regions as well. The disease is characterized by the appearance of chlorotic areas on the leaves and occasionally the chlorotic areas turn yellow and are seen interspersed with green patches. The infection may be reduced by the use of seeds which are collected from healthy plants and by acid treatment of seeds. Infected plants in the field should be removed to prevent further spread of the disease.

Insect pests

Fruit borer (Heliothis* sp.*): It has become a serious pest in some of the states. The caterpillars feed on the vegetative parts and cut holes on unripe as well as ripe fruits. The damaged fruits may be picked up and destroyed completely. It may be controlled by the spray of carbaryl 50 WP @ 1.5 g/litre of water at fortnightly interval. The infested fruits should be picked up and buried in soil before spray of insecticide. The spray may be repeated after two weeks. Larvae and eggs in the field may be picked up by hand and killed. All matured fruits should be picked before spraying.

Serpentine leaf mineor (Liriomyza trifolii): Maggot mines into the leaf and feeds on the mesophyll of the leaves making serpentine mines. As the larva grows the diameter of the mine increases. Pupation is in soil and the entire life-cycle is completed in about 15 days. If infestations occur at the late stage of the crop, no chemical control may be needed. If early and severe, spray triazophos 40 EC @ 2 ml/litre.

Jassids (Empoasca* sp.*): The insects suck the leaves causing curly appearance. The spray of insecticides as suggested for leaf curl virus at about two weeks interval gives a satisfactory control.

Root-knot nematode (Meloidogyne* sp.*): The minute worm like pest causes stunting of plants, yellowish to bluish colouration of leaves, followed by knot like irregular swellings on roots. The plant shows wilting in hot-weather and may result in pre-mature death. A proper crop rotation with non-Solanaeceous crops reduces infection. The use of nematode resistant varieties like 'Arka Vardan' is beneficial. Organic additives from neem and chrysanthemum, followed by big marigold profoundly minimized the incidence of nematodes in tomato fields. It also can be effectively controlled by the soil application of nematicide Nemagon (active ingredient is DBCP) @ 6–7 litres/ha. At least two-year crop rotation with nonhost crops like cereals, groundnut, cotton, pigeon pea and vegetables like cole crops, bulb crops, spinach, bottle-gourd is recommended.

Whitefly (Bemisia tabaci): Whitefly adults are tiny (0.06 inch, 1.5 mm long), yellowish insects with white wings. Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. They cause damage to leaves by feeding, which causes leaves to yellow and curl, and by the production of honeydew, which causes leaves to appear shiny or blackened (from sooty mould growing on the honeydew). Spray imidacloprid @ 0.4 ml/l or thiomethoxam

25 WP @ 0.3 g/l, if white fly incidence is observed. The fruit may be harvested before spray of insecticides or after 5–6 days of spray.

Spider mite (Tetranychus urticae): The red spider mite is one of the common pest on tomato. Unfortunately it can also prove quite difficult to control. The red spider mite is a tiny wingless insects - up to about 1 mm long. Young and adult mites feed on the leaves extracting sap and soft plant cells. The first sign of a red spider mite infestation are either small spider webs - often high up on the plant - or white speckling on the upper surface of the leaves. As the attack progresses, they take on a bronzed appearance and may wither and die. A fine webbing is produced, strung between parts of the plant or under the leaves. Using a magnifying glass the red spider mites and their eggs can be seen on the undersides of the leaves. Serious damage to the plant is only done when population numbers dramatically increase resulting in leaf, flower and even fruit death. Spray plants with a fine mist of water, twice daily, as the spider mite can only thrive in hot dry conditions. If red spider mite incidence is noticed, spray Neem soap 1% or neem oil 1% mixed with acaricide like dicofol 18.5 EC (1.5 ml/l) or wettable sulphur 80 WP (3 g/l). Spray lower surface of the leaves where mites are generally found.

Physiological disorders

Cat face: This is a physiological disorder. The damaged fruits are distinguished by the distortion of the blossom end and have ridges, furrow, indentations and blotches. A good number of varieties are free from this physiological disorder.

Sun injury: The fruit surface exposed to the sun may become yellow or develop brown burnt areas. This may be reduced by the use of varieties with abundant foliage so as to cover the fruits with leaves. While picking the fruits from the vines, care should be taken not to turn the plants. Foliar diseases may be controlled timely so as to avoid defoliation leading to exposure of fruits to the sun.

Harvesting and yield

Tomato fruits may be harvested at various stages of maturity as under:

1. ***Green stage:*** The fruits are fully developed but are green and suitable for transporting to distant markets;
2. ***Pink stage:*** Some of the portions are red or pink and the fruit is not fully ripe. It is most suited for local markets;
3. ***Ripe stage:*** The major portion of the fruit is red and the softening begins. It may be picked for home or table use;
4. ***Full ripe stage:*** The fruit develops maximum colour and turns soft. It is used for processing purposes. After picking, the fruits are graded and sorted out into, cracked, bruised, injured fruits and well matured ripe fruits. For marketing purposes Bureau of Indian Standard (BIS) is advocated.

An average yield of 250 q/ha is expected from the improved tomato varieties but best management practices can produce as high as 400 q/ha. Average yield of hybrids varies from 600 to 750 q/ha.

The green tomatoes can be stored for 4–5 weeks at 12°–15°C and 85–90% relative humidity at an average freezing point of 30.4°C. At the same freezing

point, riped tomatoes can be stored for 7–10 weeks at 7–10°C with a maintained relative humidity of 85–90%.

Seed production

Cultural requirements for seed production of tomato are similar like fruit production. However, the following aspects are to be considered at seed production:

Planting time: The best time for planting the seed crop is January-February in plains since it is not affected by the viruses at low temperature. Tomato seed production is highly influenced by environmental factor, particularly temperature which has significant effect on all stages of plant growth and development. Day and night temperature and the variation between the two has pronounced effect on growth, flowering, fruiting and yield of fruits and seeds in tomato, but the night temperature is a critical factor for fruit set in tomato. Plants could set fruits abundantly when the night temperature is between 15°C and 20°C and the day temperature is about 25°C. Various experiments have revealed that temperature above 32°C leads to reduction in fruit-set which is also reduced at a temperature below 15.5°C due to poor pollen dehiscence.

Irrigation: Tomato needs very careful irrigation which should be sufficient in right time but waterlogging should be avoided at all times during the crop growth. Quality of fruits improves by optimum moisture supply during flowering and fruit setting. Heavy irrigation after a long dry spell may result in fruit cracking. Similarly providing irrigation late in the season may result in watery fruits of poor quality. However, irrigation should be given according to the local need.

Training, pruning and staking: Training of tomato plants with the help of wires or ropes is claimed to result in early ripening, higher yield of better quality fruits and seeds, lesser disease incidence, easier intercultural operation and harvesting. Pruning side shoots and staking have claimed to have higher yield, uniform and larger fruits.

Isolation: Tomato is normally self-pollinated crop. Self-fertilization being favoured by the position of the receptive stigma within the cone of anthers and the normal pendant position of the flower. Though the stigma is receptive at the anthesis, anthers do not dehisce until about 24–48 hr later. Cross-pollination of tomato flowers to the extent of about 5% may occur through insects. The minimum isolation distance between different cultivars of tomato for seed production is relatively short. However, the minimum recommended isolation distance between different varieties is 50 m.

Roguing: Plants showing different characters to the type must be removed. Roguing is done at different stages of crop growth as under:

1. *Before flowering:* Plants showing different growth habit and foliage characteristics than the particular variety should be rogued out.
2. *Early flowering and fruit setting stage:* Off-types are rogued out judging the size and shape of immature fruits.
3. *Fruiting stage:* The off-types are identified examining the fruit characteristics like shape, size, colour etc.

Rotation: Tomatoes like brinjal crop are susceptible to many of the soil borne

diseases and therefore rotation must be taken into consideration to prevent pest and disease build-up. Generally 3–4 years should elapse between successive tomato or brinjal crop.

Harvesting: Seed fruits are allowed to ripen to maturity on the plant. Only completely coloured and matured seed fruits are harvested. The mark of the two sepals (calyx) cut off should be checked carefully to ensure that only pollinated fruits are harvested.

Seed extraction: The following methods have been suggested by many workers for tomato seed extraction.

1. *Fermentation method:* In this method the selected ripe fruits are harvested and kept in wooden or plastic containers for two to three days until the fruits become soft. They are crushed by hand and no fruit juice is allowed to drain out. Entire mass is kept for 24–72 hr depending upon temperature. Flesh will float at the top and seed will settle down at the bottom. The fermented mass is removed and the seeds are sieved and cleaned with fresh clean water and dried. Longer fermentation may damage the seed.
2. *Separation with sodium carbonate:* This method is relatively safe and can be used for small quantities of seed in cooler temperate areas where the fermentation method is not used. The pulp containing the extracted seeds are mixed with equal volume of a 10% solution of sodium carbonate (washing soda). The mixture is left up to two days at room temperature after which time the seed is washed out in a sieve and subsequently dried. The sodium carbonate method of extraction tends to darken the testa of the seed and is, therefore, not normally used for commercial seed.
3. *Separation with hydrochloric acid:* This method is often favoured by large commercial producers as it produces a very bright clean seed sample. The hydrochloric acid treatments is often combined with later stages of fermentation. 567 ml of concentrated hydrochloric acid stirred into 10 liters of seed and pulp mixture and left for half-an hour is successful. After the extraction seeds must be dried as quickly as possible. A common method is to spread the seed in screen-bottom trays which are placed on racks out of doors so that the air passes both above and below the screens. The trays are often stirred to get the full effect of the solar energy. Occasional stirring of the seed speeds the drying process. Drying of tomato seed is done up to the moisture content of 8%. Tomato seeds will store safely for four or more years after being properly dried and stored.
4. *Seed yield:* Tomato seed yields are highly variable, depending up on several factors like the cultivar, season and management practices. However, in commercial field production of tomato, the rule is that seed weight should be 1% of the fresh fruit weight, i.e., 10 kg seeds/1000 kg fruits. However, to produce 1 kg of tomato seeds, the quantity of fruit required varied from 120–200 kg depending up on the variety. However, an average seed yield of 145 kg/ha can be obtained.

BRINJAL

Fig. 2. Brinjal.

Brinjal is said to be the native of India with the secondary centre of origin as China. More than 16 species, many of which are closely related to brinjal, are found grown in various parts of India. It was domesticated in India from the species *Solanum incanum* In English it is known as eggplant, in French as *aubergine* and in Hindi as *baingan.*

Brinjal is a grown in almost all the parts of the country and is a main vegetable of the plains and is available more or less throughout the year. In India brinjal is grown in an area of 6,92,000 ha with a production of 12634,000 tonne and productivity of 18.3 tonne/ha. The major brinjal producing states are—Odisha, Bihar, Karnataka, West Bengal, Andhra Pradesh, Maharashtra and Uttar Pradesh (NHB, 2011).

Used primarily as a cooked vegetable, brinjal is popular for the preparations of various dishes in different regions of the country. The 100 g of edible fruits contains 91.5% of water, 6.4% of carbohydrates, 1.3 g of protein, 0.3 g of fat and 0.5 g of mineral matter. It contains certain medicinal properties and used in *ayurvedic* medicines.

Botany

Brinjal, *Solanum melogena* L. (syn. *Solanum ovigerum* Dunal; *Solanum trongum* Poir.) belongs to the family Solanaceae and genus *Solanum.* There are 3 main botanical varieties under the species *melongena*, viz., round or egg-shaped cultivars which are grouped under var. e*sculentum;* long slender types which are included under var. s*erpentintum;* and dwarf brinjal types which are put under var. *depressum.*

Solanum melongena is a delicate, tropical perennial often cultivated as an annual in temperate climates. It grows 40–150 cm tall, with large, coarsely lobed leaves that are 10–20 cm long and 5–10 cm broad. Semi-wild types can grow larger, to 225 cm with large leaves over 30 cm long and 15 cm road. The stem is often spiny. The flower is white to purple, with a five lobed corolla and yellow stamens. The fruit is fleshy, has a meaty texture. It is less than 3 cm in on wild plants, but larger in cultivated forms. The fruit is botanically classified as a berry and contains numerous small, soft seeds which are edible, but have a bitter taste because they contain nicitinoid alkaloids

It has erect or semi-spreading habit. The fruit is a berry, borne singly or in clusters. It is a self-pollinated crop but the cross pollination to the extent of 30–40% has been reported. The somatic chromosome number is 2n=24 (Peter, 1998; Rashid and Singh, 2000).

Floral biology and pollination: Brinjal flowers are large, violet coloured and solitary or in clusters of two or more. Flower consists of calyx: sepals five, united, persistent; corolla: petals 5, united, usually cup-shaped; androecium: stamens five, alternate with corolla; gynoecium: carpels are united, ovary superior. In most varieties the perfect flowers are borne singly and opposite the leaves. The stamens dehisce at the same time the stigma is receptive so that self-pollination is the rule although there is some cross-pollination by insects. Depending on the length of styles, four types of flowers are reported in brinjal, viz., (*i*) long-styled with large ovary, (*ii*) medium-styled with medium size ovary, (*iii*) pseudo-short styled with rudimentary ovary, and (*iv*) true short-styled with very rudimentary ovary. It is observed that long and medium-styled flowers produce fruits whereas pseudo-short and short-styled flowers fail to set fruits. The anthesis and dehiscence in brinjal are mainly influenced by the daylight, temperature and humidity. Usually anthesis starts from 7:30 AM and continues up to 11 AM. Peak time for anthesis is 8:30–10:30 AM. The pollen dehiscence starts from 9:30–10 AM. Fruit setting in brinjal varies from 70–86% in long styled flowers, while the short styled flowers did not set fruits (Rashid and Singh, 2000). Brinjal is highly cross pollinated due to heteromorphic flower structure, called as heterostyly (Peter, 1998).

Breeding

The breeding methods adopted in brinjal are pure line selection, pedigree method, backcrossing, heterosis breeding. Brinjal varieties and hybrids are developed exclusively in India. Nurki, a local brinjal cultivar, is the source for the variety Pusa Purple Cluster which is resistant to bacterial wilt and little leaf diseases. Many local varieties and land races like Dorli, Benares Giant, Khandesh Local, have contributed genes for resistance to jassids.

A genetic variation with regard to colour, shape, vegetative growth and presence or absence of spines exists among the indigenous materials. Earlier, more emphasis was laid on the selection among the existing strains, which resulted in the release of varieties like 'Pusa Purple Long', 'Pusa Purple Round' and 'Pusa Purple Cluster' by the Indian Agricultural Research Institute, New Delhi. The oblong variety 'Pusa Kranti' was developed at the same institute for North Indian conditions. The high-yielding and good-quality varieties, 'Arka Sheel' (dark purple long), 'Arka Shirish' (long green), 'Arka Kusumakar' (small green clusters) and hybrid 'Arka Navaneet' (purple round) have been developed for the southern plains by the Indian Institute of Horticultural Research, Bengaluru.

Yield increase up to 40–50% in hybrids over the better parent has been reported. The hybrids invariably gave large fruits of superior quality. Hybrid vigour upto 156.9% over the better parent in the cross 'Arka Kusumkar' × 'Supreme' was obtained. The hybrid combination 'IIHR 22-1 × Supreme', named as 'Arka Navneet' proved to be the best combination for fruit quality and yield (Nath *et al.* 2002).

(Gupta *et al.* 2000) developed a new brinjal variety, 'Pusa Ankur', a semi-erect, non-spiny variety. It bears oval round, small-sized (60–80 g), and dark purple, attractive fruits. It is an early bearing variety, which takes 45 days for first picking after transplanting. (Prasanth *et al.* 2002), studied the performance of

hybrids in brinjal. Promising hybrids with high yield and less susceptible to shoot and fruit borer were, 190 × Annamalai, 221 × Annamalai (3.363 kg/plant), 193 × MDU 1 (3.281 kg/plant), and 195 × Annamalai (3.122 kg/plant).

The major diseases/insect pests affecting brinjal crops are phomospis blight, bacterial wilt (*Pseudomonas solanacearum* E.F. Smith), and fruit and shoot borer. The cultivars 'Annamalai', 'Pusa Purple Cluster', JC 1 and JC 2 were observed to be resistant to bacterial wilt at Asom Agricultural University, Jorhat. Other sources of resistance to bacterial wilt are, 'Long Green' and 'SM 81'. Sources of resistance to phomopsis blight utilized at IARI, Delhi, is the line 'lla'.

Improved cultivars

Pest and disease resistant cultivars

Pusa Bhairav: Developed at IARI, New Delhi. Resistant to *Phomopsis* blight; fruits dark purple, glossy, attractive and 12–15 cm long. First picking 80–85 days after sowing. Yield 300 to 350 q/ha.

Pusa Purple Cluster: Developed at IARI, New Delhi. Plants erect, tall, compact, sturdy with purple pigmentation all over. Fruits borne in clusters of 4–6 fruits; moderately resistant to bacterial wilt. First picking 85–90 days after sowing. Yield 250 q/ha.

Pusa Anupam: Developed at IARI, New Delhi. Plants medium tall, fruits in cluster of 3 to 5, cylindrical, tender, purple colour and resistant to wilt. First picking 95–100 days after sowing. Yield 370 q/ha.

Pant Samrat: The fruits are ready for harvest 70 days after transplanting. The deep purple, long fruits are borne in clusters. Plants are tall, erect, with dark green leaves. It is resistant to bacterial wilt and phomopsis blight diseases and to shoot and fruit borer and jassids. The average yield varies from 300 to 500 q/ha. Released by GBPUAT, Pantnagar, Uttarakhand.

Arka Neelkanth: Developed at IIHR, Bengaluru. Tall, compact plants, bearing small fruits in clusters, purple fruits, resistant to bacterial wilt, duration 150 days. Yield 43 tonne/ha.

Arka Keshav: Developed at IIHR, Bengaluru. Long fruits in clusters, green leaves with purple glossy fruits, resistant to bacterial wilt. Duration 150 days. Yield 450 q/ha. Recommended for Karnataka.

Manjri: Fruits are medium-sized, round, rosy in colour with white stripes and very tasty. Resistant to wilt and yield is 300–350 q/ha. Recommended by the Department of Agriculture, Maharashtra.

DBHL-20: Released at IARI, New Delhi. Fruits are long, dark purple, glossy, weighing 90–100 g and it takes about 55 days from transplanting to first harvest. Its average yield is 524 q/ha.

Swarna Mani: Released at ICAR-RCER, Patna. Moderately resistant to bacterial wilt. Yield: 600–650q/ha

Swarna Shyamli: Released at ICAR-RCER, Patna. Resistant to bacterial wilt. Yield: 600–650 q/ha.

Pusa Purple Round: Developed at IARI, New Delhi. Plants are tall with spreading nature. The fruits are round, purple coloured, each weighing about

400–500 g. Highly resistant to "little leaf" virus disease. The fruits are ready for harvest 80–90 days after transplanting and average yield varies from 250 to 300 q/ha in plains of India. It does not fruit in summer.

Arka Anand (F_1): Developed at IIHR, Bengaluru. An hybrid variety suitable for summer and rainy season. Resistant to bacterial wilt. Fruits are green, medium long, borne in clusters. Duration 140–145 days. Yield 600–650 q/ha.

Swarna Shakti (F_1): Released by ICAR-RCER, Patna. Resistant to *Phomopsis* blight. Yield: 700–750 q/ha.

Swarna Ajay (F_1): Released by ICAR-RCER, Patna. Resistant to bacterial wilt and Phomopsis blight. Yield: 700–750 q/ha.

Long fruited cultivars

Pusa Purple Long: Developed at IARI, New Delhi. Early fruiting with purple colour; 20 to 25 cm long fruits. First picking 75–80 days after sowing. Yield 300 q/ha.

Pusa Kranti: Developed at IARI, New Delhi. Fruits stocky, uniformly long, attractive dark purple colour. First picking 80–85 days after sowing. Yield 350 q/ha.

Kashi Komal: Developed at IIVR, Varanasi. Long fruited, prolific bearing, fruits light purple. Maturity 65–70 days. Yield 700–720 q/ha. Suitable for all brinjal growing areas.

Kashi Prakash: Developed at IIVR, Varanasi. Plants semi- upright, maturity 80–85 days. Yield 680–700 q/ha. Recommended for Uttar Pradesh, Bihar and Jammu and Kashmir.

Kashi Tarun: Developed at IIVR, Varanasi. Tall and erect plants. Maturity 75–80 days after transplanting. Yield 700–750 q/ha.

H 4: Fruits are long [15–20 cm], thick with deep shining purple colour. The average fruit weight is 125–150 g. Maturity 75–80 days after transplanting. Yield 250 q/ha. Released from HAU, Hisar.

Arka Sheel: Developed at IIHR, Bengaluru. The fruits are medium long, thick with deep shining purple colour. Yield 350–400 q/ha.

Punjab Barsati: Fruits are 18–20 cm long and 4–6 cm in dia. The fruits are dark purple, soft and shining. Released from PAU, Ludhiana.

Arka Nidhi: Developed at IIHR, Bengaluru. Fruits are 20–25 cm long and 3–4 cm in dia and purple.

Hisar Jamuni: Fruits are light purple, 10–15 cm long with 3–4 cm dia. Released from HAU, Hisar.

NDB 25: Fruits are 15–20 cm long and dark red. Released from NDUA&T, Faizabad.

Arka Shirish: Developed at IIHR, Bengaluru. The fruits are green, extra long with very few seeds. It is an early variety and is ready for harvest 60–65 days after transplanting. The average yield varies from 350 to 400 q/ha.

Krishnanagar Green Long: The fruits are long [25–30 cm], green, flesh with scanty seeds. Maturity 75–80 days after transplanting. Yield 250–300 q/ha. It is a very popular variety cultivated in south India

Pusa Shymala: Released at IARI, New Delhi. Fruits long, glossy, dark purple,

weighing 80–90 g. Average yield 390 q/ha. Maturity 50–55 days.

DBL-02: Released at IARI, New Delhi. Plants are non-spiny with erect branches, having light purple pigmentation partially on younger leaves, mid-rib and veins. Fruits are long, violet-purple with round distal end, each fruit weighing 80–90 g. Average yield 382 q/ha. Maturity 55 days from transplanting.

Vijay Hybrid: Fruits are long, thick with deep purple. They are ready for harvest 90–100 days after transplanting. The average yield varies from 270–280 q/ha. Released by Vegetable Research Station, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.

Round-oval fruited cultivars

Pusa Uttam: Developed by IARI, New Delhi. Fruits oval round, glossy, dark purple and medium-sized; 4–5 fruits/kg. First picking 85 days after sowing. Yield 410 q/ha.

Pusa Upkar: Developed by IARI, New Delhi. Fruits round, glossy, dark purple and medium-sized; 4–5 fruits/kg. First picking 90 days after sowing. Yield 400 q/ha.

Pusa Bindu: Developed by IARI, New Delhi. Plants pigmented all over, fruits small, oval round, glossy, dark violet purple, about 14 fruits/kg. First picking 85–90 days after sowing. Yield 300 q/ha.

Azad Kranti: Selection from a local cultivar. fruits oblong, thick and dark purple.

APAU Shymala: Developed by APAU, Hyderabad. Local selection, fruits round and dark purple.

Kashi Sandesh: Developed by IIVR, Varanasi. Round, purple fruits, medium sized. Maturity 76 days after transplanting. Yield 780 q/ha.

Pant Rituraj: Developed by GBPUAT, Pantnagar. The Plants are semi-dwarf and semi-spreading in nature with dark green leaves having purple tinge on the margin. The fruits are round, medium in size with dark purple shining colour. Maturity 60–80 days after transplanting. Yield 300 q/ha.

Surti Gola: Fruits are medium-sized, round with purple colour. Soft but watery in taste and yield is 275–300 q/ha.

Krishnanagar Purple Round: Developed by CSAUA&T, Kanpur. Fruits are large, round, slightly oval, dark purple, flesh with very less seeds and yield is 250–300 q/ha. Suitable for West Bengal.

Type-3: Developed by CSAUA&T, Kanpur. Fruits are round with light purple colour and weigh 300 g–400 g. This variety can be grown in spring-summer also. Yield is 250–300 q/ha.

Punjab-8: Developed at PAU, Ludhiana. Fruits are round and medium-sized with light purple colour. Yield is 250–300 q/ha.

Punjab Bahar: Developed at PAU, Ludhiana. Fruits are round with deep shining purple colour, are fleshy with less seeds, it weight from 200 g–300 g and yield is 350–400 q/ha.

Hissar Shayamal: Developed at HAU, Hisar. Fruits are round, short with dark colour.

Arka Navneet (F_1): This is An F_1 hybrid developed at IIHR, Bengaluru. Fruits

are large, oval, shining and dark purple. Average fruit weight varies from 400 to 450 g and it is free from bitter Principal. Yields about 750 q/ha.

Pusa Anmol (F_1): An hybrid variety with attractive dark purple, oblong fruits. It is early variety; maturity 70–75 days after transplanting. Yield is 300–350 q/ha.

Pusa Hybrid -6: Developed at IARI, New Delhi. Plants semi-erect, vigorous, fruit round, glossy, attractive purple colour, each weighing 200–250 g. First picking 85–90 days after sowing. Yield 400–600 q/ha.

Pusa Hybrid -9: Developed at IARI, New Delhi. Plants with strong, upright branches; fruit oval round, glossy, purple. Each fruit weighs about 250 g. First picking 85–90 days after sowing. Yield 500–600 q/ha.

Cluster bearing cultivars

Pusa Ankur: Developed by IARI, New Delhi. Plants semi- erect; fruits small, oval round, glossy, purple; about 15 fruits/cluster, each fruit weighs 100 g. First picking 80–85 days after sowing. Yield 450 to 650 q/ha.

Arka Kusumakar: Developed by IIHR, Bengaluru. The finger-shaped fruits are borne in clusters, light green. This is very commonly cultivated variety in South India. The average yield varies from 350 to 400 q/ha and fruits are ready for harvest 70–80 days after transplanting.

Climate and soil

The brinjal is also susceptible to frost as in the case of tomato. It requires a long and warm growing season. The plants should not be transplanted in the field until the daily mean temperature reaches 18.3°–21.1°C. A daily mean temperature of 23° to 27°C is most favourable. Cool nights and short summers are unfavourable to the crop. It can grow well up to an altitude of 2,000 m above sea-level. From sandy loam to heavy clay, all soils are suitable for brinjal but heavy loam soils have found to be the best. Optimum *p*H range is 5.5–6.0.

Cultural requirements

Planting time: Brinjal can be grown just at the same time when the tomatoes are grown. The seed sowing in the nursery is done in December-January for spring crop and in June-July for rainy winter crop in plains. In hills, seeds are sown in March-April.

Nursery raising and seed rate: The seeds are sown in well prepared nursery beds. Nursery beds are to be prepared 15–20 cm high with finely prepared soil mixed with well decomposed farmyard manure. Usually the soil mixture for the bed should have one part soil, one part sand and one part compost. The nursery is sown on raised beds of 1.25 m width and 20 cm height. The brinjal seed is light and its germination percentage is 75–80. Seeds can be treated with dimethyldithio carbamate 75 WP (0.2%), i.e., thiram @ 2.5 g/kg of seeds to avoid fungal infection. The seeds should be sown in lines. Uniform irrigation and mulching after each irrigation should be practised to facilitate aeration. Three to four handful of urea dissolved in 30 litres of water can be sprinkled in nursery beds after about a fortnight of germination to get healthy and vigorous seedlings. The seedlings of about 15 cm high are ready for transplanting in 5–6 weeks.

To get better crop establishment and to have uniform and healthy seedlings which are free from pests and diseases the time of planting, it is advised to use protray raised seedlings.

For raising seedlings required for 1 ha, 300–350 g seeds are required for open pollinated varieties, whereas 100–120 g seeds are required for hybrids.

Land preparation and spacing: Deep, fine loamy soil with a good drainage is most favourable for the growth of brinjal. Soil *p*H should be neutral or slightly acidic. The land should be deeply ploughed and well prepared before the seedlings are transplanted. Farmyard manure or compost should be incorporated into the soil during 1st ploughing.

The planting distance depends upon the soil fertility, growing season and cultivar. Usually, 75 cm × 60 cm and 90 cm × 90 cm distance between rows and plants is given to vigorous growing, round and high yielding cultivars; 45 cm × 45 cm spacing is given to early and dwarf types and 60 cm × 45 cm spacing is given to semivigorous or midseason types.

For Open pollinated varieties a spacing of 90 cm × 50 cm between the rows and between the plants, respectively is being followed. This will again depend upon the fertility of the soil. In case of F_1 hybrids the common spacing followed is 90 cm × 60 cm or 100 cm × 50 cm (in south Indian conditions).

Ridges and furrows are prepared required spacing. Plain beds can also be prepared after the land is well levelled.

Manure and fertilizers: The fertilizer requirement of brinjal depends upon soil type, crop rotation, season, genotype and the region of growing. About 25 tonne/ha farmyard manure is required. For open pollinated varieties a fertilizer dose of 120 kg N, 80 kg P and 50 kg K/ha is recommended. 60 kg N and entire quantity of P and K fertilizers are applied as basal dose and the remaining 60 kg N is applied as top dressing 30 days after transplantig.

For F_1 hybrids a fertilizer dose of 180 kg N, 150 kg P and 120 kg K/ha is recommended. Entire quantity of P and one-thirds N and half of K fertilizers are applied as basal dose and the remaining half of K and one-thirds N are top dressed 30 days later. The third dose of 60 kg N is applied 50 days after transplanting.

Prabhu *et al.* (2005) reported that on the hybrid COBH 1 as nitrogen dose was increased from 100,120,175 to 200 kg/ha, fruits and shoots became succulent and subsequently became susceptible to fruit and shoot borer injury. But application of phosphorus (@50, 70,100 kg/ha) and a constant dose of potassium @ 100 kg/ha promoted early maturity and hardening of plant tissue which enabled them to escape from pest injury. Pest damage was minimum @ 100 kg N and P.

Transplanting: Brinjal seedlings are transplanted when the seedlings are 4–6 weeks old or at 3–4 leaf stage. Ridges and furrows are prepared at appropriate distance depending upon the fertility of the soi1.The field is irrigated lightly, one day before planting. Holes at at appropriate spacing are made and seedlings are planted on the sides of the ridges with one seedling per hole. Light irrigation is given after planting.

Intercultural operations

Irrigation: High yields of brinjal are obtained under optimum moisture

conditions. Timely irrigation is essential for good fruit set and its development. It is recommended to irrigate at an interval of 3–4 days during summer and at 10–12 days interval during winter. Irrigation is given according to local need taking into consideration soil type, stage of crop growth and weather 'condition.

Weeding: Brinjal seedlings are transplanted when they are 4–6 weeks old or at 3–4 leaf stage. Ridges and furrows are prepared at appropriate distance depending upon the fertility of the soi1.The field is irrigated lightly, one day before planting. Holes at appropriate spacing are made and seedlings are planted on the sides of the ridges with one seedling per hole. Light irrigation is given after planting.

Top dressing: Top dressing with fertilizers may be done as mentioned above under manure and fertilizers.

Mulching: It done may be with black polyethylene, as in case of tomato crop. Drip system of irrigation effectively reduces the water use, controls the weeds and increases the yield. With drip system and black polythene mulching, irrigation requirements reduced by about 30% and yield increased by 18 to 20%.

Pest and disease management

Diseases

Damping-off (Causalorganism) Phytophthora or *Pythium* spp.*:* Due to the attack of this disease the seedlings rot at the ground level and then fall over the ground. It can be controlled by sterilizing the nursery soil before sowing and treating the seeds with captan 50 WP (0.2%). Drenching of nursery beds with captan 50 WP (0.2%) is also useful before sowing.

Phomopsis blight (Phomopsis sp.*):* The foliage is attacked at any time during the season. The lesions usually appear first on the leaves and later on the fruits near the ground. The spots are clearly defined, circular, grey to brown and have a light-coloured centre. The affected leaves may turn yellow and die. It may be reduced by the use of seeds obtained from disease free plants and treatment of the seeds with captan 50 WP (0.2%). After fruit formation the crop may be sprayed with zineb 75 WP (0.2%). The spray may be repeated after 10–12 days. Use of some sticker is useful.

Alternaria leaf spot (Alternaria melongenae, and *A. solani):* The two species of *Alternaria* occur commonly, causing the characteristic leaf spots with concentric rings. The spots are mostly irregular, 4–8 mm in dia meter and may coalesce to cover large areas of the leaf blade. Severely affected leaves may drop off. *A. melongenae* also infects the fruits causing large deep-seated spots. The infected fruits turn yellow and drop off prematurely. Spraying copper oxychloride 50 WP (0.3) or zineb 75 WP (0.2%) effectively controls leaf spots.

Cercospora leaf spot (cercospora solani –melongenae): The leaf spots are characterized by chlorotic lesions, angular to irregular in shape, later turn grayishbrown with profuse sporulation at the centre of the spot. Severely infected leaves drop off prematurely, resulting in reduced fruit yield. Diseases can be managed by growing resistant varieties such as Pant Samrat which is resistant to

both the leaf spots. Spraying copper oxychloride 50 WP (0.3%) or zineb 75 WP (0.2%) effectively controls leaf spots.

Little leaf: It is a very serious viral disease in some of the states. The leaves become smaller, the petioles get shorter considerably, many buds appear in the axils of leaves, and internodes get shortened and give the plants a bushy appearance. Removal of the diseased plants in the initial stages and fortnightly spray of insecticide as suggested in tomato crop for control of aphids, jassids and fruit fly till the fruit set may help to check the spread of the disease which is transmitted by insects, *Eutettix hycitis* and *Empoasca devastans.*

Bacterial wilt (*Pseudomonas solanacearum*)*:* This disease has gained importance in several parts of India. A satisfactory solution to this problem is that the cultivation of brinjal may be avoided in wilt sick plots and wilt resistant varieties such as, Arka Neelkanth, Arka Keshav, Arka Nidhi, Arka Anand (F1), Pant Samrat, may be grown.

Insect-pests

Brinjal shoot- and fruit-borer (Leucinoides orbonalis): It is the most serious insect-pest of brinjal. The borer or caterpillar attacks the plant from nursery and continues till the crop remains in the field. It becomes inactive during winter. The caterpillars bore into the young shoots and fruits as a result of which the shoots wither and dry up, while the fruits become unfit for consumption and in severe cases even rot. The infected shoots should be removed and destroyed. Ratoon crop should be avoided and suitable crop rotation should be followed. The infestation can be reduced with the spray of carbaryl 50 WP @ 3 g/litre of water. The fruits are harvested 7–10 days after spraying.

Shoot and fruit borer resistant varieties like B 544, Pusa Purple Long, Arka Kusumakar, IHR 191, H 165, are recommended to overcome the problem of shoot and fruit borer.

Stem-borer (Euzopherea perticella): The caterpillars bore into the stem and often kill the plant. The infested plants or plant parts should be removed and destroyed. The plants may be sprayed with crabaryl 50 WP @ 3 g/litre after harvesting the fruits and the next harvest must not be made within 1 week of spray.

Epilachna beetles (Epilachna* spp.*): Leaf tissue is eaten between the veins. The leaves may be completely stripped to the mid-vein, and small areas eaten out and/or shallow holes may be present on the fruit surface. On both sides of the leaves the beetles will be present. Adults fall to the ground or fly when you disturb them. The young normally stay in place. Due to their yellow colour, they can easily be found. Their sizes vary. Collect and destroy leaf eating *Epilachna* beetle grubs and adults. Spray any contact insecticide like carbaryl 50 WP @ 3 g/l or quinalphos 40 EC (1.5 ml/l), if required to control *Epilachna* beetle

Jassids (Empoasca* sp.*): The leaf hopper sucks sap from the leaves causing curling of leaves. It may be controlled by the spray of insecticides as suggested for leaf curl virus of tomato. Jassids are controlled by spraying malathion (0.1%) or dichlorvos (0.05%) 20 days after transplanting. The fruits may be harvested before spray and must not be harvested for a few days after the spray.

Aphid (Aphis gossypii): Aphids suck the cell sap and prohibit the normal crop growth. Besides direct damage, the sucking pest acts as vector for virus borne diseases. Aphids are controlled by spraying malathion (0.1%) or dichlorvos (0.05%) 20 days after transplanting. The fruits may be harvested before spray and must not be harvested for a few days after the spray.

White fly (Bemisia tabaci): White flies suck the cell sap and prohibit the normal crop growth. Besides direct damage, the sucking pest acts as vector for virus borne diseases. White flies are controlled by spraying malathion (0.1%) or dichlorvos (0.05%) 20 days after transplanting. The fruits may be harvested before spray and must not be harvested for a few days after the spray.

Red spidermite (Tetranychus* spp.*): The mite is a pest of brinjal. Low relative humidity favours mite multiplication. Different stages of mites are found in colonies covered by white silky webs on lower surface of leaves. Nymphs and adults suck cell sap and white patches appear on leaves. Affected leaves become mottled, turn brown and fall. Acaricides like dicofol (0.05%) and sulphur 85 WP (0.3%) gives effective control of mites. Collection and burning of severely infested plant parts reduces further multiplication of mites. Proper irrigation and clean cultivation are essential to keep the pest population under control.

Root-knot nematodes (*Meloidogyne* sp.). The plants become stunted and the leaves become chlorotic. Nodules are formed on the roots. It may be controlled by the soil treatment of nursery beds with carbofuran (Furadan-3 granules) @ 7 g/m^2 of area. Proper crop rotation will help in the reduction of nematode population. Use of nematode resistant varieties like 'Hissar Lalit' is helpful.

Harvesting and yield

Brinjal fruits are harvested for the market when they have developed to a normal size, have good colour, are immature, tender and have not lost culinary qualities. Frequency of harvesting depends on the size of fruit. Small-sized fruits are harvested more frequently than bigger or heavy fruits. When fruits look dull, it is an indication of over maturity and loss of quality. Pressing the thumb against the side of the fruit can test the maturity of the fruit. If the pressed portion springs back to its original shape, the fruit is too immature. At harvesting, the calyx and stem end are left attached to the fruit. Large, round varieties should be handled with care.

Depending on the variety and the season, the average yield varies about 350–450 q/ha for open pollinated varieties, while for hybrids the average yield will be 650–750 q/ha.

The fruits can be stored for 2–3 days during winter and 1–2 days during summer under ordinary conditions, but it can be kept for about a week in a fairly good condition at 7.2°–10°C and 85–95% relative humidity.

Seed production

The normal crop production method is followed for the crop raised for seed production also. The following aspects are to be considered at the brinjal seed production:

Isolation: Brinjal, although self pollinated, can outcross to a considerable

extent. It is highly cross pollinated due to heteromorphic flower structure, called as heterostyly (Peter, 1998). It is, therefore, essential to isolate the seed crop from other varieties to avoid contamination and to produce pure seeds. An isolation distance of 400, 200 and 100 m for breeder seed, foundation seed and certified seed production, respectively, is recommended.

Roguing: Seed growers should be well acquainted with the characterization of the variety so that they may effectively rogue out the off types and undesirable plants at different stages of crop growth. The following three roguing stages have been suggested:

1. *Before flowering:* By examining plant colour, growth habit and foliage characteristics such as shape, size and posture, off type plants may be rouged out.
2. *At early flowering and fruit development:* By observing general plant habit, vigour, degree of spineness, off type plants may be rouged out.
3. *At fruiting:* Off types can be identified on the basis of fruit characteristics like shape, size, colour etc. and the off type plants may be rouged out.

Rotation: Brinjals are susceptible to many of the soil pests and diseases associated with other members of Solanaceae and the rotation must be taken into consideration. Generally four years duration should elapse between successive brinjal crop or other genera in Solanaceae family.

Harvesting: To ensure that seed development is complete, the fruits are usually handpicked at a later or ripen stage than for the market crop. Seeds should be collected from first or second tier fruits as those have a higher seed weight and germination rate than seeds collected from fruits beyond the second tier.

Seed extraction: There are two basic methods used for the extraction of brinjal seeds: wet extraction and dry extraction. The wet extraction is favoured for large-scale seed production whereas the dry extraction is employed for small-scale seed production.

In wet extraction, the harvested fruits are stored for 5–7 days at room temperature until they become soft. This allows the seeds to mature fully. The fruits are crushed or cut into thin slices. These are then softened by soaking till the seeds are separated from the pulp. Since the brinjal fruit pulp is relatively dry, it requires extra water during and after crushing and would be allowed to stand overnight to facilitate seed separation from the flesh.

In dry extraction, the ripened fruits are harvested and dried in the sun until they shrivel. During drying of purple and purple black fruits the skin colour turns to coppery brown. The fruits are then hand beaten to extract the seed. This method is used for small-scale seed extraction.

Cleaning and drying of seeds: After extracting and washing, the seeds are cleaned and dried. Drying is done by spreading the seeds in the partial sun light for few hours for one to two days up to a moisture content of 8% or below. Seeds will remain viable for five or more years, if properly stored.

Seed yield: The variation in seed yield is due to environmental factors, crop management practices and varieties. The average seed yield is 500 kg/ha, but good yield may reach 600–700 kg/ha. Fresh seeds of brinjal do not germinate satisfactorily and thus show a certain degree of dormancy.

CHILLI

Fig. 3. Green Chilli.

Chilli (originated in South America) is spread into the new world tropics before subsequent introduction to Asia and Africa. It is now widely grown throughout the tropics, sub-tropics and warmer temperature region of the world. In India, its introduction is believed to be through the Portuguese in the 17th century. Chilli is also known as hot chilli, hot pepper and chilli pepper; in Hindi red or dry chilli is known aslal *mirch,* and green chilli is known as *hari mirch.*

As per the *Report of APEADA* during 2006–07, the area under green chilli and pepper was 5,760 ha and production was 59,190 tonne with a productivity of 10.27 tonne/ha, whereas the area under red/dry chilli was 6,80,330 ha and the production was 978,610 tonne with a productivity of 1.43 tonne/ha. During 2010–11, in India capsicum was grown in an area of 10,000 ha with a production of 127,000 tonne and productivity of 12.7 tonne/ha (NHB, 2011). Maximum chillies are produced in Andhra Pradesh, followed by Karnataka, Odisha, West Bengal, Maharashtra, etc. Guntur in Andhra Pradesh is known for chillies.

Chilli is grown in tropical areas of the country, whereas the sweet pepper is grown at a little higher elevation also where the climate is relatively mild. Chilli and sweet pepper are consumed by every Indian. Chili peppers are consumed fresh or in a variety of processed products in many cuisines world-wide. They are used as condiments or spices to add flavor or pungency to dishes. Use in processed products has increased dramatically in recent years. There is hardly a vegetable where chilli is not used as a condiment while cooking. The chillies are used as green as well as dry in the powdered form. It is a rich source of vitamins A and C. The chillies are usually more pungent than the sweet pepper. The pungency in chilli is due to the presence of the chemical ‘capsaicin’ and the bright red at the ripening stage is due to the pigment ‘capsanthin’. 100 g edible portion contains 92.4 g water, 1.2 g protein, 29 g cal energy, 11 mg Ca, 870 IU vitamin A, 175 mg vitamin C, 0.06 mg B_1, 0.03 mg B_2 and 0.55 mg niacin.

Botany

The common chilli is *Capsicum annuum* var. *longum*, whereas the sweet pepper is *Capsicum annuum* var. *grossum* l. They belong family Solanaceae and the genus *Capsicum.* The misleading name ‘pepper’ was given by Christopher Columbus upon bringing the plant back to Europe. At that time pepper corns, the fruit of *Piper nigrum*, an unrelated plant originating from India, was a highly prized condiment; the name ‘pepper’ was at that time applied in Europe to all known spices with a hot and pungent taste and so naturally extended to the newly

discovered *Capsicum* genus. The most commonly used alternative name of the plant family, 'chile', is of Mexican origin, from the Nahuatl (a group of peoples native to southern Mexico and Central America, including the Aztecs) word *chilli* or *xilli*.

The chilli includes a large number of cultivars and is most important economically. The fruit varies in size from 1 to 20 cm in length, from thin long to conical and thick fleshed blocky shapes. It includes both pungent and non-pungent varieties but most of the varieties grown in India are pungent, varying from very pungent to non-pungent. *Capsicum annuum* should not be confused with 'black pepper', *Piper nigrum*, which belongs to a distantly related plant family (Piperaceae).

Early taxonomic classification of the genus *Capsicum* resulted in description of nearly 100 good species and botanical varieties. There are many cultivars differing from each other in shape and colour of the fruits, pungency and position of fruits. Pepper is divided in to five groups based on fruit shape as under:

(i) *Capsicum annuum* var. *annuum* Longum Group: Long pepper, with drooping enlongated pungent fruit.
(ii) *C. annuum var. annuum* Grossum Group: sweet or bell pepper having large, puffy fruit with a depression at the base and usually furrowed sides. The fruit is red or yellow with a mild flavour.
(iii) *C. annuum* var. *annuum* Cerasiforme Group: The cherry pepper, a pungent variety.
(iv) *C. annuum* var. *annuum* Conoides Group: The cone pepper, also pungent with conical or oblong cylindrical fruits.
(v) *C. annuum* var. *annuum* Fasciculatum Group: Red cluster with fascicled fruits, red and extremely pungent.

Based on taxonomic and genetic studies all the types and varieties mentioned above have been included under *C. annuum* and listed the pungent variety Tabasco, together with some other uncommon varieties, as belonging to *frutescens*. All the species of *Capsicum* both wild and cultivated are diploids, 2n=2×=24.

Floral biology and pollination: Chilli flower is normally solitary but occasionally borne in small cymes of leaf axils. The calyx is five lobed and corolla is five parted and white, but occasionally purple. The five stamens attached to the base of corolla are separated. The bluish anthers dehisce by splitting longitudinally. The single style is usually longer than the stamens and stigma is club-shaped. The ovary generally has three locules. Pepper tend to blossom and set fruit earlier under short day conditions. Fruits of the capsicum is a pod like berry with a short, thick peduncle. The shape of the fruit varies from a flattened oblate to long, slender and tapering, the size also ranges from very small to large fruit of sweet pepper. Seeds within the fruits mature as the fruit ripens. The seed is borne in a compact formation on the placentae and usually at the basal end of the fruit. Peppers are generally self pollinated, but some cross-pollination can occur between and within the cultivars of the two species (*C. annuum* and *C. frutescens*). Up to 68% cross pollination has been reported in India. Bees, ants and thrips are the possible agents of pollination. Anthesis takes place some times after the flowers have opened. Flowers remain open for 2–3 days. The flowers open in the morning between 2

AM and 10 AM. The anthers normally dehisce an hour after the flower opening. Flower opening and anther dehiscence to a large extent depend on the weather condition. During cold and cloudy days, the opening is delayed. In case of sweet pepper, anthesis commences at 7 AM, which continues up to 11 AM, with peak at 7:15 AM and anther dehisce after 30 min of anthesis. The stigma remains receptive up to two days after anthesis

Breeding

Chillies and sweet peppers can be crossed easily and viable seeds can be obtained in F_1 and F_2 generations. The germplasm is maintained by NBPGR and other ICAR centers at All India Coordinated Vegetable Improvement Project, Lam [Guntur, Andhra Pradesh], [Kovilpatti, Tamil Nadu] and [Kalianpur, Uttar Pradesh]. Several local varieties of chillies are grown by the farmers. A great genetic variation exits in chillies and sweet pepper with regard to shape, size, pungency and pigmentation of the fruits. Most important strains have been reported from various parts of the country where it is intensively grown for dry as well as green chillies. The important centres of growing chillies are Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu. Madhya Pradesh, Rajasthan, Bihar and Punjab. Efforts were made by the breeders to evolve suitable strains which are being widely cultivated. The popular local cultivar 'Kashmiri Mirch' of Kashmir is not pungent but have red colour. The local varieties of 'Byadgi' of Karnataka and 'Sankeshwar' of Maharashtra are grown during rainy season. In Andhra Pradesh, there are several local cultivars like Nallapadu, Warangal, Lanka chilli, Seema Mirapa, Golcanda Mirchi *etc.,* are commonly grown. Likewise, different states have different cultivars that are adapted to local conditions (Swarup, 2006).

Overall, the breeding methods of improvement include, pure line selection, pedigree method of selection followed by hybridization and backcrossing. Many improved varieties such as 'Aparna', 'Co 1', 'Co 2', 'Musalwadi', 'Arka Lohit' and 'Kalyanpur Red', have been developed by pure line selection from land races or heterogenous local cultivars. Several varieities like 'Andhra Jyoti', 'Pusa Jwala', 'Pusa Sadabahar', 'Pant C-1', 'Pant C-2', 'Punjab Lal', *etc.,* have been developed by hybridization. Backcrossing is useful in transferring a single gene controlled character into a desired variety particularly disease resistance [Swarup, 2006]. Transgression of useful genes for biotic and abiotic stresses, for disease and pest resistance is possible through utilizing resistant genes from wild and weedy species of *Capsicum* species.

Improved cultivars

Pest and disease-resistant cultivars

Arka Sweta (F_1): The CMS based chilli F_1 hybrid developed by IIHR, Bengaluru, using male sterile line. Suitable for irrigated cultivation for both *kharif* and *rabi*. High yielding with 280–300 q/ha green chilli, and 45 q/ha of dry chilli. Fruits light green, smooth, long (10–12×1.2cm), pendent, turning red on maturity. Field tolerant to viruses. Suitable for green chilli market with light green and smooth fruits.

Arka Suphal (F_1): An F_1 hybrid. Developed by IIHR, Bengaluru. Plants tall and erect. Fruits green, medium long, pungent, suitable for irrigated and rain fed cultivations. Tolerant to powdery mildew, Duration 180 days. Yield 250 q/ha of green chilli and 30 q/ha of dry chilli. Suitable for Karnataka, Kerala, Andhra Pradesh, and Telangana.

Arka Meghana (F_1): An F_1 hybrid is developed by IIHR, Bengaluru. Plants tall and spreading. Fruit length 10 cm, very early type [24 days for 50% flowering after transplanting]. Fruits green and turn deep red on maturity. Duration 120–140 days. Tolerant to powdery mildew and viruses. Yield 335 q/ha of green chilli and 50 q/ha of dry chilli.

Arka Harita (F_1): An F_1 hybrid developed by IIHR, Bengaluru. Plants tall, spreading, fruits dark green [10 cm long]. Duration 150–160 days, resistant to powdery mildew and viruses. Yield 382 q/ha of green chilli and 58.6 q/ha of dry chilli.

Pusa Sadabahar: Developed by IARI, New Delhi. Plants erect dark green foliage with large leaves. Fruits 6–8 cm long, erect bearing habit in clusters of 6–14 fruits/cluster. Highly pungent, field resistance to leaf curl virus complex. Suitable for both the seasons. Maturity 150–170 days. Yield 110–125 q/ha of green chilli, and 15–20 q/ha of dry chilli.

Bhagyalakshmi (G–4): Developed by APAU, Lam, Guntur. Leaves narrow, dark green, fruits olive green turning bright red on ripening. Fairly tolerant to diseases and insects. Suitable for sowing in both the seasons. Maturity 150–170 days. Yield 110–130 q/ha of green chilli and 10–13 q/ha of dry chilli.

Pant C-1: Developed by GBPUAT, Pantnagar. Plant short statures, more primary branches, fruit erect bearing, small in size, highly pungent, 5.5 cm long. Light green fruits turn red at maturity. Tolerant to leaf curl virus. Suitable for both winter and summer. Maturity 90–130 days. Yield 100–120 q/ha of green chilli and 9–11 q/ha of dry chilli.

Cultivars suitable for green and or dry chilli

Sindhur (CA-960): APAU, Lam, Guntur. Fruits long, 7 to 8 cm, per carp light green and turning deep red on ripening, surface smooth, mildly pungent. Suitable for both winter and summer. Maturity 130–180 days. Yield 120–140 q/ha of green chilli and 11–12 q/ha of dry chilli.

Kashi Anmol: Developed by IIVR, Varanasi. Plants determinate, fruits are compact, dark green, pungent [0.5%] capsicin, suitable for long distance transport, Harvesting 50–55 days after transplanting. Yield 250 q/ha of green chilli. Recommended to Uttar Pradesh, Karnataka, Madhya Pradesh, Uttaranchal, Jharkhand, Chathisgarh.

Kashi Vishwanath (F_1): Developed by IIVR, Varanasi. Red ripe fruits in 220 days and yield 200 q/ha. It is a cytoplasmic male sterile based hybrid. Suitable for dry fruit production in Uttar Pradesh, Bihar, Madhya Pradesh, Jharkhand, Uttarakhand, Karnataka, Andhra Pradesh, Delhi and Haryana.

Kashi Early: Developed by IIVR, Varanasi. For both green and dry fruits. Yield 300 q/ha in 240 days. Andhra Pradesh, Madhya Pradesh, Jharkhand, Uttarakhand, Karnataka, Delhi, Punjab, Haryana.

Arka Lohit: Developed by IIHR, Bengaluru. Plants tall, fruits dark green, turn deep red on maturity (capsanthin 0.205%). Highly pungent, suitable for irrigated and rain fed cultivation. Duration 180 days yield 250 q/ha of green chilli and 30.0 q/ha of dry chilli. Suitable for Odisha, Maharashtra and Karnataka.

Pusa Jwala: Developed by IARI, New Delhi. Plants dwarf, light green fruits, 9–10 cm long, thin, turning red at ripening, dry fruits wrinkled. Suitable for both winter and summer in plains and March-April in the hilly region. Mildly pungent. Maturity 130–150 days. Yield 75–80 q/ha of green chilli and 7–8 q/ha of dry chilli.

Punjab Lal: Developed by PAU, Ludhiana. Plant dwarf, bushy with dark green foliage, fruits erect bearing medium sized, dark green turning red at ripening. Rich in capsaicin content suitable for both winter and summer. Maturity 120–180 days. Yield 100–120 q/ha of green chilli and 9–10 q/ha of dry chilli.

Cultivar suitable for oleoresin extraction

Arka Abhir: A 'Paprika' variety. Developed by IIHR, Bengaluru. Plants tall, fruits light green, wrinkled, has low pungency [0.05%]. Suitable for oleoresin extraction. Duration 160–180 days. Yield 200 q/ha of dry chilli.

The other commercially important varieties of chilli developed by State Agricultural Universities are, namely, APAU, Lam, Guntur—'Andhra Jyothi', 'LCA 206b', 'Aparna', 'X-235'; 'TNAU', Coimbatore—'Co-1', 'Co-2', 'Co-3'; TNAU, Kovilpathi—'K-1', 'K-2'; TNAU, Periyakulam- 'PKM-1'; TNAU, Palur- 'PLR-1'; 'TNAU', Paramkudi- 'PMK-1'; TNAU, Madurai- MDU-1; PAU, Ludhiana— Punjab Lal, 'Punjab Surkh', 'Punjab Guchhedar', 'CH-1'; MPKVV, Rahuri—'Musalwadi', 'Sankeshwar-32', 'Agnirekha', 'Phule Jyothi', 'Phule Suryamukhi', 'Phule Sai', 'RHR-CPMR-50-1'; GBPUAT, Pantnagar—'Pant C-2'; UAS, Dharwad- 'Byadagi Kaddi' and 'Byadagi Dabbi'.

Climate and soil

Chilli is grown in both tropical and sub-tropical areas. A temperature ranging from 20° to 25°C is ideal for chilli. A warm humid climate favours growth while dry weather enhances fruit maturity. A frost free period of 4 months with maximum temperature of 35°C and minimum temperature not below 10°C is optimum for raising this crop. Chilli crop for ripe dry fruits is extensively raised in *kharif* (June-October); however, for green fruits, chili crop is raised throughout the year in India under irrigated condition.

Chillies can be grown on many types of soils but well drained loamy soils are preferable. In general, light soils are suitable for early crop while clay loam and silty loams are well suited for heavy crop. However, the germination and early vigour were affected in saline soils. It is extensively grown as a rainfed crop in the black cotton soils in South India. The optimum soil *p*H is 6.0–6.5. For dry fruit production, chillies are grown in heavy black soils in Maharashtra and Karnataka.

Cultural requirements

Planting time: Like brinjal and tomatoes, chillies can also be grown as *kharif*,

rainy and *rabi* crops in the frost free areas of the plains and as only summer and rainy season crops in areas where frost and severe winter occurs. Chillies can be grown in South India and Maharashtra almost throughout the year. The main seasons of seed sowing are in June-July [*kharif*], and September-October [*rabi*] and January-February.

Chilli crop for ripe dry fruits is extensively raised in *kharif* (June-October); however, for green fruits, chili crop is raised throughout the year in India under irrigated condition.

Nursery raising and seed rate: Seedlings can be raised as mentioned for tomato and brinjal. Seeds are sown in nursery beds and seedlings become ready for transplanting in about 5–6 weeks when they are 15–20 cm high.

Depending up on the variety 400–500 g of seed is required for raising seedlings required for 1 ha.

Land preparation and spacing: The land should be prepared well for transplanting and should be irrigated one day before transplanting. Usually the seedlings are transplanted in rows about 60–75 cm apart either in plain beds or on the ridges depending on the type of soil and availability of irrigation facilities. The plants in the row are kept about 30–45 cm apart. The row-to-row spacing and plant to plant spacing within the rows varies according to the variety, season and region.

Manure and fertilizers: For irrigated crop 25 tonne of farmyard manure (FYM), 150 kg N, 75 kg P, 75 kg K/ha, and for rainfed crop 25 tonne of FYM, 100 kg N, 50 kg P, 50 kg K/ha are required. Entire quantity of FYM, 1/3 N, 1/2 P and 1/2 K should be applied as basal dose at the time of land preparation. One-thirds N and remaining P and K are to be applied 5–6 weeks after transplanting at the earthing up. Remaining 1/3 N can be applied 3–4 weeks after the first top dressing.

Transplanting: The field should be irrigated one day before transplanting. Usually the seedlings are transplanted in rows about 60–75 cm apart either in plain beds or on the ridges depending on the type of soil and availability of irrigation facilities. The plants in the row are kept about 30–45 cm apart.

Intercultural operations

Irrigation: It is given immediately after transplanting. About 4–5 weeks after transplanting top dressing fertilizer on the sides of ridges and earthing up is done to bring plants to the middle of the ridge. Frequency of irrigation depends on soil type and season, and normally done once in 8–10 days during winter and 4–5 days interval during summer. Excess irrigation during flowering stage to be avoided to reduce flower dropping. During rainy season yields can be substantially increased by providing supplementary irrigations whenever the dry spell exceeds one week. The most critical stages of moisture stress are initial establishment stage and preblooming and fruit development stage.

Weeding: Two to three hand weedings are essential.

Top dressing: 1/3 N and remaining P and K are applied 5–6 weeks after transplanting and earthing up of plants is done. Remaining 1/3 N can be applied 3–4 weeks after the first top dressing.

Pest and disease management

Diseases

Damping-off (CAUSAL ORGANISM Pythium, Phytophthora and *Pellicularia* spp.*):* The disease attacks seedlings at or just below the soil level and the seedings gradually die. The stem of the seedling decays at the soil surface and finally it collapses due to shrinking of tissues of the stem near the ground. The disease may be controlled by sterilization of the nursery soil by steam or Formalin and by treating the seeds with captan 50 WP (0.2%). The nursery should also be drenched with captan 50 WP (0.2%) after germination of seeds, if disease is seen.

Anthracnose and dieback (CAUSAL ORGANISM Colletotrichum capsici): The foliage, stem and fruits are attacked by this disease, causing 10–75% loss of fruits. In severe cases it causes the dieback of the plant, especially by *COLLETOTRICHUM gloeosporiodes*. High humidity is conducive for this disease. The disease can be controlled by seeds treatment with captan 50 WP (0.2%) before sowing; following crop rotation with other non-Solanaceous crops; and by spraying copper oxychloride 50 WP (0.2%) or zineb 75 WP (0.2%) at 7–10 days interval.

Powdery mildew (CAUSAL ORGANISM Levelillula sp.*):* It is serious especially during summer. The vegetative parts are damaged by the appearance of white mealy growth which ultimately leads to defoliation. It may be reduced by the application of sulphur 85 WP (0.2%) at 10–15 days intervals.

Fruit rot (CAUSAL ORGANISM Phytophthora capsici): It is more serious during rainy season. Fruits become watery and fall off. Brownsih spots appear on fruits at the point of contact between the fruit and the soil. The fruit decays and becomes unmarketable. The disease is effectively controlled by spraying mancozeb 75 WP (0.2%) or copper oxychloride 50 WP (0.3%).

Bacterial wilt (Pseudomonas solanacearum): Though chillies are not affected by this disease as much as tomato or brinjal, sweet pepper varieties are susceptible to this wilt. In this case, there is a sudden wilting of plants which do not recover at all. The disease is known to be soil borne. It is difficult to control the disease. The only solution seems to be to grow resistant varieties, Capsicum cv. 'Arka Gaurav', reported to be tolerant to this disease.

Early blight (Aternaria solani): Dark brown to black spots with concentric rings are formed on leaves and stems and dark decayed spots on the ripe fruits. The crop should be sprayed with ziram 80 WP (0.2%). This spray may be repeated after 10–15 days interval. The seeds from infected plants may not be used and the clean seeds may be treated with captan 50 WP (0.2%) as in the case of damping off disease to avoid infection, if any. A proper crop rotation should be followed avoiding Solanaceous crops.

Viral diseases: The most important virus is leaf curl virus (LCV), causing curling of the leaf margins inwards and upwards and crumpling of interveinal areas. In severe cases, leaves fall off, checking the growth of the plant. The disease is transmitted by thrips and aphids. Diseases can be controlled by uprooting and burning the plants showing infection to avoid further infection; by spraying imidacloprid @ 0.4 ml/litre or thiomethoxam 25 WP @ 0.3 g/litre to control the insects transmitting virus by growing chilli varieties like 'Pant C 1', 'Pusa

Sadabahar', 'Punjab Lal', 'Punjab Surkh', 'Puri Orange', 'Puri Red', 'Pusa Jwala', which are also reported to be tolerant to leaf curl virus.

Other viral diseases like cucumber mosaic virus (CMV), tobacco mosaic virus (TMV) and potato virus Y (PVY) are also important diseases of chilli and sweet pepper. The control lies with the development of resistant varieties. For TMV, 'Pant C 1', and 'Pant C 2' are tolerant whereas varieties like 'Punjab Lal', 'Punjab Surkh', 'PSP 11', 'LCA 235', 'LCA 305' and Punjab Guchhedar are resistant. For CMV, 'PSP 11', Pusa Sadabahar, Punjab Lal are resistant.

Insect pests

Thrips (Thrips* sp.*): These are tiny sucking insects which feed on leaves and lacerate the tissues. The damage is done at all the stages of plant growth and they are more severe when plants begin to flower. These insects cause curling of the leaves and the yield is reduced considerably. They may be controlled by the spraying carbaryl 50 WP @ 3 g/litre or acephate 75 SP @ 1.5 g/litre or fipronil @ 1 m/litre at fortnightly interval.

Aphids (Aphis gossypii* or *Myzus persicae): Both adults and nymphs suck the sap from young leaves and shoots. Foliar application of dimethoate @ 1 ml/l is recommended whenever aphid attack is observed.

Chilli tobacco caterpillar/pod brer (Spodoptera litura): Adult moth is light brown with dark spotted wings; larvae colour varies depending on feed crop; pupa is dark brown. The prime defoliator of chilli plants. The caterpillar s eat leaves and later on bore the pods, which result in the deterioration of quality and market price of the product. The early instar larvae feed voraciously on the undersurfaces of leaves, leading to their skeletonization. They also feed on flower buds, flowers, calyx. In later instars, they disperse, become solitary and nocturnal. The control measures are timely spraying the crop with quinalphos @ 4 ml/litre or carbaryl 50 WP @ 3 g/litre of water, starting from flower bud formation. Spodo-Cide, a specially designed formulation that uses Nuclear Polyhedrosis Virus (NPV) for very effective control of tobacco caterpillars. The virus is ingested by feeding caterpillars that become pale and start dying within 2–5 days in the characteristic "head down" position, hanging on only with their abdominal pro-legs.

Yellow mite (Causal Organism Polyphagotarsonemus latus): This is a sucking pest. The symptoms are, downward curling and crinkling of leaves; leaves with elongated petiole; and stunted growth of plants. Foliar application of wettable sulphur 80 WP (0.3%) or dicofol (0.2%) is recommended against mites.

Harvesting and yield

Chilli peppers are harvested for two purposes; one for green vegetable and the other for dry chilli. The green chillies are harvested when they are fully mature and before they turn to red. They are picked at frequent intervals, possibly twice a week. Dry chillies are harvested when pods are fully nature, turn to red and half dried on plants and after harvest they are further subjected to drying. They are then bottled in condiment products, air dried, or dried and ground for use as spice or accent food ingredients (paprika, hot pepper oil). The crop starts yielding green fruits 2 months after transplanting and dry chillies 90 days after transplanting.

The crop lasts for 5–6 months after transplanting depending upon duration of the variety. 4–5 pickings of green chillies or 2–3 pickings of redripe chillies is done.

From the rainfed crop green chilli yield of 70–100 q/ha and dry chilli yield of 7.5–11.0 q/ha can be obtained. From the irrigated crop green chilli yield of 200–250 q/ha and dry chilli yield of 20–25 q/ha can be obtained.

From fresh ripe fruit 25–40% of dry fruits can be obtained depending upon the varieties which differ in quantity of seeds and the thickness of the inner wall. In the villages fruits are dried by spreading on the floor or roof of the houses in the sun. With the indigenous method it takes 10–15 days to dry, whereas commercially it is dried at about 54.4° C in 2–3 days. Green chillies and peppers can be stored for about 40 days at 0°C and 95–98% relative humidity. Dried chillies can be kept for months together in dry places well protected from insect pests. Minimum physiological loss in weight was observed in fruits packed in polythene bag (100 gauge thickness).

Seed production

The cultivation practices for chilli seed production would be exactly the same as for dry chilli production. The following aspects are to be considered while taking up chilli seed production:

Rotation: Like brinjal and tomato, chilli is also susceptible to many soil borne diseases. Therefore, a period of 2–3 years elapse between successive chilli crop or other solanaceous crops is recommended.

Isolation: Chilli is considered as self-pollinated crop, but significant cross pollination does occur if plants are placed together. A minimum isolation distance of about 400 m and 200 m, respectively, for Foundation seed and Certified seed production between two varieties is recommended.

Roguing: Plants should be rogued based on the plant and fruit characters as a whole rather than the individual character. Off type plants should be removed as soon as they are observed. When the fruits begin to show their final colour of red or yellow, occasional plants with off colour fruits have to be removed. In addition to off types, diseased plants are also to be removed.

Harvesting and threshing: Red ripe fruits are picked, and macerated mechanically to separate the seeds. Harvested fruits can also be put in gunny/plastic bags (upto 60–70% of bag) and tied. Then the bags are beaten with long sticks. Then, by winnowing the seeds can be separated. Early harvested fruits give poor quality seeds with low viability and vigour. Fruits harvested at colour breakage stage (turning of green colour to red or yellow) have high viability. Seeds are cleaned to free pulp and skins and dried in the partial sun to below 8% moisture content before storage.

Seed yield: Average seed yield of chilli varies from 450 to 500 kg/ha.

SWEET PEPPER

Sweet pepper is a cultivar group of the species *Capsicum annuum.* Sweet peppers are native to Mexico, Central America and northern South America. Pepper seeds were later carried to Spain in 1493 and from there spread to other European, African and Asian countries. Today, China is the world's largest pepper producer,

Fig. 4. Sweet pepper

followed by Mexico and Indonesia. The common name of sweet pepper is pepper (in the United Kingdom and Ireland), bell pepper, green pepper and capsicum (in India, Australia and New Zealand). In Hindi it is known as *Simla mirch.*

Sweet peppers are unrelated to the spice pepper plant that produces the ground black pepper commonly found on the tables. Sweeet peppers contain no 'capsaicin'- the compound that gives the kick to chilli peppers. They are high in vitamin C [one medium green bell pepper contains 177% of the recommended dietary allowance for vitamin C], and as they mature and turn colour, the vitamin A content rises. The brighter coloured peppers tend to be sweeter than green peppers because the sugar content increases as the pepper matures. Peppers are also excellent sources of dietary fibre and provide small amounts of several other vitamins and minerals. Mild, sweet peppers have established themselves as staples in salads and as integral components of almost all cuisine. Peppers are usually harvested in the immature 'green' stage for use in relishes, salads, stuffings and for flavour in many cooked dishes.

Sweet peppers are fleshy, blocky of various shapes - more like a bell and hence named as bell pepper. Almost all the varieties are very mild in pungency and some of them are non-pungent and as such could be used as stuffed vegetable.

Botany

Sweet pepper (*Capsicum annuum* var. *grossum*) belongs to the family Solanaceae and the genus *Capsicum.* The *Capsicum annuum* should not be confused with 'black pepper', *Piper nigrum*, which belongs to a distantly related plant family (Piperaceae). Based on fruit shape bell pepper has been included under the group *grossum*; this group has large, puffy fruit with a depression at the base and usually furrowed sides; the fruit is red or yellow with a mild flavour. The diploid chromosome number of bell pepper is 2n=24 (Peter, 1998). Floral biology and pollination habit is same as that of chilli. The fruits of bell pepper and chilli are botanically called 'berry'. Like chilli this is also a cross pollinated crop.

While the sweet pepper is a member of the *Capsicum* genus, it is the only *Capsicum* that does not produce capsaicin, a lipophilic chemical that can cause a strong burning sensation when it comes in contact with mucous membranes. The lack of capsaicin in sweet peppers is due to a recessive form of a gene that eliminates capsaicin and, consequently, the 'hot' taste usually associated with the rest of the *Capsicum* genus. Sweet peppers are botanically fruits, but are generally considered in culinary contexts to be vegetables. Cultivars of the plant produce fruits in different colors, including red, yellow, orange, chocolate brown, lilac, ivory, deep purple and green. Bell peppers are sometimes grouped with less

pungent pepper varieties as "sweet peppers".

Floral biology and pollination: The flower of sweet pepper is hermaphroditic and self pollinating. The sweet pepper (*Capsicum annum*) flower has 5–7 petals of the colour white, greenish, and in some varieties purple. The flower is self-fertile, self-pollinating, producing plenty of pollen and nectar, and lacking any scent. In the sweet pepper there usually appears one flower for each node. The anthers are carried on filaments that emerge from the base of the corolla and their number is equal to the number of petals. In each anther there are two chambers that open length-wise. The amount of time it takes the anthers to open is dependent on the temperature - at low temperatures the opening of the anthers is delayed and so too the release of pollen grains. Five days after the opening of the anthers the corolla falls off with the stamens. In a normal flower, 50,000 to 1,40,000 pollen grains may be found (the actual amount depends on variety). The vitality of the pollen decreases as the temperature increases. During the warm months, such as August, up to half of the amount of pollen grains can degenerate in certain varieties due to the high temperature. The optimal germination of pollen in the sweet pepper flowers is achieved at a temperature around 25°C. The bumblebee's visits to the sweet pepper flowers bring about either self-pollination or cross pollination.

Breeding

Much breeding work has been performed on sweet pepper in temperate regions. Many cultivars, at present mostly F_1 hybrids, are commercially available for glasshouse and field production. Capsicum shows rather strong heterosis effects for plant growth traits and yield. Capsicum is very appropriate for the development of F_1 hybrids, with cultivars superior in yield, uniformity and disease resistance. Hybrid seed is produced by hand emasculation and pollination of the right inbred lines, a very labour intensive method. Capsicum breeding work carried out at IIHR, Bengaluru, has resulted in the development of three high-yielding capsicum varieties, viz. 'Arka Basant', 'Arka Mohini' and 'Arka Gaurav'.

Improved cultivars

California Wonder: Upright plants, medium green foliage, good cover, bearing fruits continuously. Fruits smooth, blocky, 3–4 lobed, dark green turning red on ripening 6.5 – 8.5 cm long, 6.5–7.5 cm in dia, erect bearing habit, thick flesh. Suitable for sowing in plains from September to October and March to April in hilly region. Maturity 90–120 days after transplanting. Yield 150–180 q/ha.

Yolo Wonder: Dwarf, bushy plant, prolific bearer, fruits blocky, smooth, 3–4 lobes, pendent, 6.5–8.5 cm long and 4.5 to 6.5 cm in dia, thick flesh, deep green turning red on ripening. Suitable for sowing in both the seasons. Maturity 110–150 days. Yield 130–180 q/ha.

Arka Mohini: Developed by IIHR, Bengaluru. Medium to large drooping fruits, dark green turning red on ripening, 3–4 lobes suitable for both the seasons in plains and March-April in hilly region. Maturity 125–140 days. Yield 180–250 q/ha.

Arka Gaurav: Developed by IIHR, Bengaluru. Fruits dark green, blocky, erect

bearing, 3 to 4 lobed, thick fleshed, medium size. Fruits turn to orange yellow on ripening. Folaige covers the fruits to avoid sun-scald. Good for both seasons. Maturity 125–150 days. Yield 180–250 q/ha.

Arka Basant: Developed by IIHR, Bengaluru. Fruits waxy (creamish white), conical, erect bearing, thick fleshed, prolific continous bearing, suitable for both the seasons. Maturity 125–140 days. Yield 150–200 q/ha.

Bharat (F_1 hybrid): Plant tall, prolific bearing fruits dark green, blocky, 3–4 lobed, thick fleshed, large size. Suitable for both the seasons. Maturity 125–140 days. Yield 150–200 q/ha. Developed by Indo American Hybrid Seeds, Bengaluru.

Pusa Deepti (F_1 hybrid): Developed by IARI, New Delhi. Plants erect, medium tall, bushy. Fruits smooth, erect bearing, conical, light green turning dark red on ripening, thick fleshed, 9–11 cm long and 3–5 cm in dia, very early fruiting, suitable for both the seasons. Maturity 90–105 days. Yield 300–350 q/ha.

Indra (F_1 hybrid): Released by the Syngenta Co. Ltd. Indeterminate plant habit with dark green foliage, thick fleshed, 3–4 lobbed, dark green blocky fruits with average fruit weight of IS0–200 g, fruits pendent and turn red on ripening.

Climate and soil

Capsicum comes up well under low temperature (24°–28°C day, 18°–20°C night and 60–80% RH) and shade [50%). Reduced transpiration under shade favours vegetative growth. Usually bell peppers perform better during *rabi* (October-February) than in *kharif* (June-September). Capsicum can be grown on a wide range of soil types, provided they are well drained to a depth at least 40 cm. Sandy loam to loam soils with high humus content are preferred but can also be grown successfully in well drained medium black soils. The ideal *p*H range is 5.4–6.8.

Cultural requirements

Planting time: Capsicum is sown in July-August or October-November. In hills they are sown in March-April while transplanting is done in April-May..

Nursery raising and seed rate: Seedlings can be raised as mentioned for tomato and brinjal. Seeds are sown in nursery beds and seedlings become ready for transplanting in about 5–6 weeks when they are 15–20 cm high. For open-pollinated varieties 300–350 g seeds and for F_1 hybrids 150-200 g seeds are needed for raising seedlings required for 1 ha.

Land preparation and spacing: The soil in the field is brought to fine tilth and the entire quantity (25 tonne/ha) of farmyard manure (FYM) is incorporated. Non-edible oil cakes like castor/pongamia/neem @ 625 kg/ha along with recommended dose of fertilizers are then applied. Ridges and furrows across the slope are prepared at the spacing of 60 cm or 90 cm. Furrows are opened and fertilizer is applied in bands and earthed up. The field is irrigated lightly one day in advance. The spacing recommended for open-pollinated varieties is 60 cm × 40 cm and for F_1 hybrids is 90 cm × 50 cm.

Manure and fertilizers: For OPEN POLLINATED varieties 25 tonne FYM, 120 kg N, 80 kg P, 50 kg K/ha and for F_1 hybrids 25 tonne FYM, 150 kg N, 100 kg P, 60 kg K/ha are recommended.

For open pollinated varieties, half of N and the entire quantity of P and K fertilizers are to be applied as basal dose. Remaining half of N is to be applied as top dressing 30 days after transplanting.

For hybrids, 75 kg N and half the quantity of P and K ferrtilizers are applied as basal dose. Remaining quantities of P and K and 40 kg N are to be top dressed 30 days after transplanting. A third dose of 35 kg N is applied 50 days after transplanting.

Transplanting: Holes are made at 40 cm or 50 cm spacing on sides of ridges and seedlings are transplanted. Because of the sensitivity of these fruits to sunburn, the seedlings are usually planted out in double rows, spaced 50–60 cm apart. Picking pathways of 50–100 cm are left between the beds, to allow easier access (without causing serious damage to the brittle branches). The plants are spaced 40–50 cm apart in the rows. Populations generally vary from 25, 000 to 40,000 plants.

Intercultural operations

About 4–5 weeks after transplanting topdressing fertilizer on the sides of ridges and earthing up is done to bring plants to the middle of the ridge. Frequency of irrigation depends on soil type and season, and normally done once in 8–10 days during winter whereas 4–5 days interval during summer. Excess irrigation during flowering flowering stage to be avoided to reduce flower dropping. During rainy season yields can be substantially increased by providing supplementary irrigations whenever the dry spell exceeds one week period.

As bell pepper varieties grown in India are of temperate origin, they start fruiting before they put up enough vegetative growth under tropical conditions. Hence, pinching of first two buds/flowers/just set fruits helps the plant to put up good vegetative growth and thus the yield.

Peppers are easily damaged when laden with fruit. For support, tie the plants to stakes using old nylons, which have some 'give' as the stems enlarge. Don't use wire twist-ties or twine which will gradually choke off or even snap the stem.

Pest and disease management

As given under chilli.

Harvesting and yield

Sweet peppers can be harvested when fully matured, green and before they turn to red and harvested only once in a week. First picking could be done 60–75 days after planting and later at 10–15 days intervals. Most commercial capsicums are harvested for about three months. Harvesting should be done at the optimal stage of maturity as dictated by the market. Fruits should ideally be picked during the cooler parts of the day and the produce protected from heat or direct sunlight. Harvesting workers should have closely trimmed fingernails to prevent mechanical damage of the produce. The produce should then be transported gently to the packaging facility. Sweet pepper varieties yield about 200–300 q/ha of green fruits, while the hybrids can yield up to 400 q/ha.

Seed production

As given under chilli.

The ripe fruits are cut opened and the seeds are scooped out and the seeds are dried under shade.

Seed yield: A seed yield of 100–150 kg/ha can be obtained depending upon the variety. ●

CHAPTER 14

Cucurbitaceous Vegetables

THE family Cucurbitaceae consists of about 117 genera and 825 species out of which about 15 different species of cucurbitaceae are being cultivated in India. They have numerous resemblances in gourd development and similarities of root habit. They are also quite similar in their internal anatomy and development.

Seed production methods including cultural practices of pumpkin, cucumber, bottle-gourd and watermelon are discussed. The cultivation methods for the production of these crops for seed are similar as growing the crops for fresh market barring some important factors followed for seed production like roguing, isolation, to allow the crop to reach full maturity, seed extraction, seed processing and storage etc.

Botany

The root system of all the economic cucurbits is extensive but shallow. Upon germination of the seed, the plants soon develop a strong taproot which may penetrate the soil to a depth of 1–2 m. Numerous horizontal laterals develop rapidly and spread widely in the soil, although branching of the taproot is not extensive below the 60 cm level.

All cucurbits are alike in their general stem morphology. The stems are branched (3–8), prostrate, trailing, hirsute to scabrous and usually angled in cross section. In most species, the stems grow to a length of several meters, and in a few species the stems may reach a length of 9–10 m. Andromonoecious, hermaphrodite, gynoecious, monoecious forms are also met with.

The fruits of the cultivated cucurbits vary largely in size, shape and colour. Fruits are essentially a berry, even though called a pepo, because of hard and tough rind (when completely mature) as in bottle-gourd. The fruit peduncle is 5–8 angular. The edible portion is placentae in cucumber and watermelon, pericarp with very little mesocarp in pumpkin, while the whole fruit in bottle-gourd.

The seeds of the cultivated cucurbits vary in size, shape, colour, the presence or absence of a margin and in the type of scar formed at the hilum. In general, each seed has a firm testa of several layers, a thin collapsed perisperm and endosperm and a large embryo. The embryo consists of two large, flat, leaf like cotyledons and a small radicle.

Cucurbitaceae family is divided into five sub-families, viz. (*i*) Fevilleae, (*ii*) Melothrieae, (*iii*) Cucurbiteae, (*iv*) Sicyoideae, and (*v*) Cyclanthereae. The

important cultivated genera are found only in the sub-families Cucurbiteae and Sicyoideae. The Cucurbiteae includes the genera: (*i*) *Citrullus,* (*ii*) *Cucumis,* (*iii*) *Luffa*, (*iv*) *Lagenaria*, and (*v*) *Cucurbita*; and the Sicyoideae includes the genus (*vi*) *Sechium.*

Flowering in cucurbits normally starts in about 40–45 days after sowing depending upon the weather condition. The sequence of flowering follows a set of pattern, namely,

1. *Male phase:* First few nodes bear only the staminate flowers,
2. *Mixed phase:* Both pistillate and staminate flowers appear in few nodes in the main axis and secondary branches in cycles; and
3. *Female phase:* Few nodes produce mostly the pistillate flowers.

In a typical monoecious sex form of cucurbits the ratio of staminate and pistillate flowers may range from 25–30:1 to 15:1, the later condition is advantageous and economical, because consequently it results in higher fruit set and yield. Generally high nitrogen, long days and high temperature promote greater number of staminate flowers.

Cucurbits exhibit a wide range of sex form such as: (i) monoecious (ii) dioecious, (iii) hermaphrodite, (iv) gynomonoecious (v) andromonoecious, and (vi) trimonoecious. In sex forms, although a species character, a wide range of exceptions have been reported in cucurbits. Though the sex of *Cucumis sativus, Citrullus vulgaris,* and *Cucurbita moschata* typically monoecious exhibit exceptional sex forms such as andromonoecious in the first two cases and hermaphrodite in the later cases in some varieties. Sex of *Lagenaria ciseraria* has been reported to be typically monoecious.

Trellising and pruning

Generally pumpkins are not trellized, but gourds can benefit from a well constructed trellis. This can allow maximization of space by controlling vine growth as well as protecting the fruit from rot. Trellising also will allow production of fruit with more uniform shape and colour and will allow longer gourds to grow straight. The most common trellis is a single overhead wire supported every 3–4 m with a strong post (such as a 10 cm × 10 cm). Posts should be set at least 60 cm into the ground with at least 2.5–3.0 m of post above ground. Vines can be trained to the trellis by tying a twine in a loose loop around the base of the plant when the plants are 30–45 cm tall. Tie the other end of the twine to the overhead wire. The vines can then be trained around the twine until they reach the wire. Secure the vines to the wire until tendrils develop to hold the vine in place. Gourds may also be grown on an arbor as long as it is no more than 1.0–1.25 m wide.

Vines of *Lagenaria* and *Luffa* spp. can be pruned lightly to increase marketable yield per vine. The first flowers produced are generally male flowers. Appearance of female flowers is greatly influenced by weather conditions. Do not be concerned, if the appearance of female flowers is delayed for several days after the first male flower appears. Most fruits are produced on the lateral branches, so pruning the main stem to encourage lateral branch growth is a good idea. For *Lagenaria* gourds, remove the end of the main stem when it reaches 3 m in length. The first three to four lateral vines can be removed on luffa gourds to increase yield. Do not prune

gourds of the *Cucurbita* type. Pumpkins are generally not pruned.

Pollination and fruit yield

As with most cucurbits, gourds and pumpkins are monoecious, producing separate male and female flowers on the same plant. As a result they must have some pollinating agent present. It is a good idea to place 3 hives of bees for each hectare of gourds or pumpkins to aid in pollination. Native bee populations are generally not prevalent enough to adequately pollinate a large planting. Avoid application of insecticides during the early and mid-day hours to prevent killing pollinating bees. Gourds and pumpkins require 7–10 bee visits per flower for complete pollination. Flowers generally only remain open for one day. Incomplete pollination produces poorly developed fruit that is often unmarketable, and reduces fruit set and thus yield.

Flowers of hard shell gourds open in late afternoon and evening, and require pollination by nocturnal insects. They can also be hand pollinated by using a small paintbrush to transfer pollen from the male to female flowers.

Pollination, fruit set and seed yield: Anthesis, pollen dehiscence and fruit set in cucurbits are influenced by environmental factors. Usually fruit set takes place early in the morning between 6:00 and 8:00 AM in crops like cucumber, pumpkin and watermelon *etc*. Optimum temperature during this period would range between 12.8° and 18.3°C. There are other cucurbits which flower later in the day and fruits set at higher temperature of mid day as in bottle gourd etc. Monoecious condition in cucurbits imposes a situation conducive to cross pollination, however, a limited percentage (20–40%) of natural self pollination takes place within the same plant. The andromonoecious condition favours a higher degree of natural self-pollination than in the monoecious condition.

For maximum fruit set and seed yield, 2–3 bee colony/ha would be required. As a single fruit of a cucurbit contains a large number of seeds, hand pollination should be followed for quality seed production in cucurbits. By hand pollination fruit set can be increased in cucurbits resulting in increased seed production. For example, about 30–35% increase in the fruit set of cucumber with hand pollination as compared to natural pollination has been observed. In case of hand pollination male and female flower should be bagged before the day of anthesis. Afterwards, when anthesis takes place, butter paper bags are opened and petals of male flower are removed and anther are gently rubbed on the stigma, then again female flowers are to be bagged for 2–3 days to avoid contamination by foreign pollen. After 3-4 days of pollination, bags can be removed.

Cucurbits are cross pollinated crops, sufficient isolation distance between two varieties is required while producing seeds. These crops require up to 1,600 m of isolation distance. Different species of Cucurbitaceae do not cross pollinate, so one variety from each species can be grown together without danger of crossing. For instance, one variety of summer squash or bush squash (*Cucurbita pepo*), one pumpkin (*Cucurbita moschata*), one watermelon (*Citrullus vulgaris*), one cantaloupe or muskmelon (*Cucumis melo*), one luffa (*Luffa aegyptiaca*), a bottle gourd (*Lagenaria siceraria*), and a cucumber (*Cucumis sativus*) could all be grown together without crossing each other.

Sponge gourd and ridge gourd should not be put together in the same field for seed production as they cross pollinate with each other. Musk melon, snap melon, and long melon are highly cross compatible with each other. The different varieties of any one of the melons mentioned above should not be grown together; otherwise these varieties would be contaminated by cross-pollination.

WATERMELON

Watermelon is reported to be originated in tropics and sub-tropics of Africa and India. In Hindi watermelon is known as *Tarbuz.* It is one of the most important Jayad vegetable crop grown from the lower Himalayan region to south India. It is cultivated in 1.66 lakh ha with a productivity of 120 q/ha in almost all states of India.

Fruits are delicious and sweet. Edible portion of watermelon contains 95.8% of water, 3.3% of carbohydrates, 0.2% of protein, 0.2% of fat and traces of mineral matter. Rind of watermelon is used in various processed items such as tuty fruity and candy.

Botany

Watermelon [*Citrullus lanatus* (Thunb.) Matsuma and Nakai] belongs to the family Cucurbitaceae and the genus *Citrullus.* The plants vines or creepers. Flowers are monoecious and are highly cross-pollinated. The fruit is a 'pepo' botanically and it varies in shape, size, colour and taste. The leaves are simple, alternate and the leaves are cordate at the base and deeply pinnated into 3 or 4 pairs of lobes. Tendrils are branched. Watermelons are generally the largest of the melon classes discussed here, but actually watermelons come in many shapes and sizes. Their rinds can vary in colour from blackish green to bright yellow and can be decorated with moon and stars, rattle snake designs, mottling and stripes. The flesh can be creamy white, salmon pink, bright orange, pale yellow and deepest red. The flesh varies in sweetness, with some being the sweetest melons available. The somatic chromose number of watermelon is 2n= 22.

Floral biology and pollination: Because watermelons have separate male and female flowers, pollen transfer is needed for adequate fruit set. Providing bees for pollination can dramatically increase yields. Without good pollination, fruit set will be less and percentages of misshapen fruits will be higher. Though historically, growers have relied on native bee populations to meet this need, losses of feral bees to disease have limited natural pollination. Bringing in 3–4 bee hives/ha during the first 3–4 weeks of flowering is recommended. The use of insecticides on the crop should be avoided at this time to prevent bee kill. However, if insecticide application is necessary, it should be done with care to avoid bee kill while bees are working the flowers. This means using less toxic compounds and spraying in the evening when bees are less active.

Breeding

Watermelon is andromonoecious, musk melon is andromonoecious or monoecious, whereas round melon is monoecious. Information on the genetics of economic characters and hybrid seed production is also available in these melons.

Studies have been made on inheritance of seed characters in watermelon, resistance to fruit fly in watermelon (Nath *et al.* 2002). A maximum of 58% and 75% increase in yield over the better parents of watermelon hybrids, viz., IIHR 20 × Crimson Sweet and IIHR 6 × Charleston Gray, respectively, was reported. 72% increase in yield in hybrid round melon. The hybrids between snap melon, long melon and musk melon showed heterois in fruit yield, which appeared to be the result of increased fruit number, fruit weight and increased flesh thickness. Two improved musk melon varieties developed were 'Arka Rajhans', resistant to powdery mildew and 'Arka Jeet' with high sugar content. In round melon, the variety 'Arka Tinda', was developed as a cross between the local strains of Rajasthan and Punjab and selected an uniform line in the F_5 generation. In long melon two superior true breeding lines were developed which possessed good fruit quality and high yield. As a result of a breeding programme in watermelon, a new variety 'Arka Manik' and a hybrid Arka Jyoti were developed (Nath *et al.* 2002).

Yadav and Luthra (2002) reported the watermelon genotype with simple unlobed marker leaves developed by hybridization of Sugar Baby × K 3566 (Russian culture). It is well suited to prevailing cropping system in irrigated areas. The leaves are simple, unlobed unlike other varieties and it is a dominant trait over lobed leaves, which help to distinguish the genotypes easily and can be used as a marker in hybridization programme. The flesh is crisp, dark red with 10–11% of TSS. The fruit weighs 4–5 kg and the fruit yield is 350–450 q/ha.

Pitachaimuthu *et al.* (2002) reported sources of resistance to watermelon bud necrosis virus (WBNV). On screening available watermelon germplasm as well as wild species, the wild species *Citrullus colosynthis* was observed to be highly resistant (<10% disease incidence). Five lines, viz., IIHR 175-2, IIHR 179, IIHR 40-2-1, IIHR 94-4-1-1 and IIHR-184 were found to be moderately resistant and remaining lines were susceptible. The identified lines and wild species can be used as sources in WBNV resistant breeding programmes. 'Arka Manik' watermelon variety has been reported to carry higher degree of resistance to powdery mildew under Bengaluru conditions and also moderately tolerant to anthracnose.

Improved cultivars

Disease resistant cultivars

Arka Manik: Developed by IIHR, Bengaluru. A selection from advanced generations of a cross between IHR 21 × Crimson Sweet by IIHR, Bengaluru. Has triple resistance to anthracnose, powdery mildew and downy mildew. Fruits oval with light green to green stripes. Average fruit weighs 6 kg, excellent granular texture, high TSS (12–15%), deep crimson flesh pleasant aroma. Average yield 600 q/ha. Has good keeping and transport quality. Duration 90–100 days it is resistant to powdery mildew and anthracnose. Can be grown as a *rabi* or summer crop in Karnataka.

Seedless cultivar

Pusa Bedana: Developed at IARI, New Delhi. A seedless watermelon. Dark

rind with faint stripes, somewhat triangular shape, tough rind, red flesh with remnants of false seeds, TSS 12–13%. Fruit weight 5–6 kg, produces 3–6 fruits per vine, very good keeping quality. Maturity 115–120 days. Yield 200–250 q/ha.

Arka Madhura: Seedless watermelon variety developed by IIHR, Bengaluru. It is a triploid. It is a high yielder (500–600 q/ha) and has good quality (TSS 13–14%). It is recommended for protected cultivation. It has a longer shelf life and fetches premium price in the market. Duration: 110 days

Dwarf cultivar

Arka Muthu: Released by IIHR, Bengaluru. It is a high-yielding variety with unique character of dwarfness (1.2 m vine length, shorter internodal length) and early maturing type (75–80 days). It has round to oval fruits with dark green stripes and deep red flesh Average fruit weight is 2.5–3 kg with T.S.S ranging from 12–14%. Fruit yield: 550- 600 q/ha.

Other cultivars

Sugar Baby: An introduction. Fruit round, 17.5–20.0 cm in diameter, weigh 3- 5 kg, rind bluish green with faint black stripes, thin, hard, and tough. Flesh medium red, firm, crisp, sweet (TSS 11–13%) of fine texture. Seeds relatively few, very small, dark tab mottled with black colour. Maturity 85–90 days after sowing. Yield 250–300 q/ha.

Arka Jyoti (F_1): Developed at IIHR, Bengaluru. F_1 hybrid between IHR 20 (a Rajasthan selection) × Crimson Sweet. An early season crop, round fruits, 5–6 kg each, each vine bearing 2–3 fruits. Rind colour light green with dark green stripes. Flesh colour deep pink, very sweet (12 to 14 per cent TSS). Average yield 800q/ha. Has excellent keeping and transport quality. Duration 90–100 days.

A good number of other varieties/hybrids, like Madhu, Durgapur Meetha, Durgapur Kesar, Durgapur Lal, Imporved Shipper and Special No:1 and PKM-1 are also available for cultivation.

Climate and soil

Watermelon requires hot dry climate and a long growing season preferably with warmer days and cooler nights. It cannot withstand frost or very low temperatures. For seed germination, an optimum moisture and a soil temperature between 25–30PC is needed. Similarly plant growth is optimum under 28–30°C, while fruiting is better at 24- 27°C. Select deep, well drained soil with sandy or sandy loam texture. The ideal pH of the soil is between 5.5 and 6.5.

Cultural requirements

Sowing time: Seeds of watermelon are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of January for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states.

Land preparation and sowing: Bring the soil to a fine tilth after 2–3 ploughings and harrowing. Apply 20–25 tonne/ha of farm yard manure in furrows. Open up

3.0–3.5 m long and 30 cm wide sowing channels across the slope, depending on the crop to be grown. Prepare 30 cm wide and 15 cm high ridges (bunds) on either side of the sowing channel. Suitable spacing between two sowing channels is 3 m and between the hills is 90 cm. Prepare irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (75 kg N, 100 kg P and 35–70 kg K/ha) in the shallow furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give a light irrigation. If hybrid, only one seed is to be sown. For gap filling seedlings are to be raised in protrays kept under protected structure. Use 15 days old seedlings for planting. About 1- 2 kg of seeds are required for sowing one hectare area. For F_1 hybrids about 300 g is sufficient.

Intercultural operations

Irrigate the crop once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (25 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Diseases

***Powdery mildew** (Erysiphe cichoracearum* D.C.*):* This is a serious disease of musk melon, watermelon, long melon, snap melon, pumpkin, gourds and cucumber. Symptoms of powdery mildew are; mildew first appears on the undersurface of the older leaves, as white fluffy circular spots, which increase in size and number, coalesce and eventually cover both surfaces. Severely attacked leaves become brown and shriveled. The fungus attacks the leaves, stem and fruits. Spray dinocap (0.1%) or hexaconazole (0.075%) or wettable sulphur 80 WP (0.3) at 15 days interval when powdery mildew disease is observed.

***Downy mildew** (Peronoplasmopara cubensis* Berk and Curt*):* The disease attacks musk melon, watermelon, long melon, snap melon, cucumber, bitter gourd and ash gourd severely. The fungus attacks only the leaves. Symptoms appear as yellow to brown angular spots on the leaves with downy growth on the lower surface. In severe cases it attacks the stems, petioles and tendrils. It causes heavy defoliation and insipid taste in matured fruits. Humid climate is more favorable than the dry climate for the growth of the fungus. The disease may be controlled effectively by spraying mancozeb 75WP (0.2%)or copper oxychloride 50WP (0.3%). Copper oxychloride should not be used on musk melon as it is sensitive to it.

***Anthracnose** (Colletotrichum* sp.*):* The disease is very serious on watermelon,

musk melon, bottle gourd, snake gourd and cucumber. In case of cucumber and musk melon reddish brown, dry leaf spots are formed resulting in shriveling and death of the leaf. In watermelon, the leaf spots are black and the foliage presents a scorched appearance. The fungus also attacks the stem and fruits. This disease can be controlled by spraying of thiophanate -methyl(O.l%) or Carbendazim (0.1%) or mancozeb 75WP (0.2%).

Alternaria leaf blight or spot (*Alternaria* spp.): Leaf spots start as small flecks, and grow into irregular brown spots (up to 1.5 cm). Leaf spots sometimes develop a target-like pattern of rings. Severely infected leaves turn brown, wither and die. Most common on muskmelon (cantaloupe), but can also infect watermelon, squash, and cucumber. This can be controlled by spraying of mancozeb (0.2%) or chlorothalonil (0.2%).

Mosaic *(Cucumis virus-1):* This virus infection causes heavy losses in cucumber. Infected plants show stunted growth and mottling of leaves. Dissemination of the virus takes place by aphids on wild cucumber and several other host plants. Clean cultivation should be followed and wild cucumber and other host plants should be eradicated. Diseased vines should be removed and destroyed. Resistant varieties should be selected for cultivation. Spraying of dimethoate or malathion or carbaryl W.P. can be sprayed to control the vectors.

Bud necrosis of watermelon: The disease symptoms are leaf crinkling, mottling, yellowing, and necrotic streaks on vines; shortened internodes; upright branches; and necrosis and dieback of the buds. This is caused by the watermelon strain of tomato spotted wilt virus (TSWV-W). This disease can be managed by the application of carbofuran/thimet-10 G @ 15 kg a.i/ha at the time of sowing the seeds. Foliar spraying of dimethoate or methyl parathion (0.05%) at 8–10 days interval and avoiding growing of other cucurbits, tomato, brinjal, chilli and capsicum, will check the further spread of the disease.

Fusarium wilt: *Fusarium* wilt is one of the economically most important diseases on watermelon and other Cucurbits. It is caused by *Fusarium oxysporum* f. sp. n*iveum*. Fungal infection may occur at any age of the plant. For young seedlings, damping-off may occur and rot in the soil, where the hypocotyls are surrounded by a watery and soft rot causing the plants to become stunted. Later, wilting occurs in more mature plants causing the plant to die. A “one-sided wilt” is a common symptom, with one or more shoots wilting and others remaining healthy. Flaccid, withered, and brown leaves, as well as vascular discoloration are common disease symptoms. The roots of infected plants may be healthy, but the vascular tissue is brown and discoloured. This disease can be controlled by giving seed treatment with benomyl [2 g/kg of seed], following crop rotation with non-host crops; growing resistant varieties; soil application of captan [0.2%].

Insect pests

Leaf miner *(Liriomyza trifolii):* Symptoms of damage are, leaves with serpentine mines; drying and dropping of leaves due to severe infestation. This pest can be managed by applying neem cake @ 250 kg/ha to soil immediately after germination and repeat at flowering. Collect and destroy cotyledon leaves infected with leaf miner after germination, as the primary infestation occurs on

cotyledon leaves. Clip off the mined leaves at weekly intervals up to 20 days after sowing. If the incidence is high remove all severely infested leaves and destroy and spray NSKE 3%.

Red pumpkin beetle *(Aulacophora* sp.*):* Symptoms of damage are, grubs feed on the roots, stem and fruits touching the soil; adults feed on leaf and flowers. The insect attacks most of the cucurbits at the seedling stage. The insects are elongated, orange coloured beetles and they feed upon the cotyledonary leaves of cucurbit seedlings. Damage is caused both by the grubs and adults. Plough the fields just after harvesting; destroy the hibernating adults; collect and destroy adult beetles, if the pest incidence is low. Spray carbaryl 50WP @ 4 g/litre.

Fruit fly *(Dacus* sp.*):* Symptoms of damage are, maggots of this fly cause severe damage to the young cucurbit fruits. The adult fly lays eggs below the skin of young fruits. The eggs hatch into maggots which feed inside the fruits; oozing of resinous fluid from fruits; distorted and malformed fruits; premature dropping of fruits and also unfit for consumption; the infested fruits carry sunken spots and under severe cases the fruits shrivel or rot. For fruit-fly-control, crush 1 kg pumpkin pulp and add 100 g *jaggery* and 10 ml malathion and keep it in the plot (8–15 places/ha). Adults of fruit fly get attracted to the fermenting pumpkin and lay eggs and get killed. Repeat this 2–3 times in cropping season. Alternatively, erect cue-lure traps @ 25 traps/ha to annihilate male flies or spray deltamethrin @ 1 ml/litre+ 1% *jaggery* or carbaryl 50WP @ 3 g/litre + 1% *jaggery* at fruit formation/ ripening stage. Collect and destroy all infested fruits by burning or burying deep into the soil.

Epilachna beetle *(Epilachna* sp.*):* The grubs and adults of this insect cause severe damage to leaves of various cucurbits. They feed on the green matter between the veins giving a lace like appearance on the attacked leaf. They can be controlled in the same way as the red pumpkin beetles.

Jassids *(Empoasca* sp.*):* These are small sucking insects (0.32 cm long), green to greenish yellow in colour. They suck the sap of the leaves which gives a shriveled appearance. They can be controlled effectively by spraying with malathion @ 1 ml/litre of water.

Aphids *(Aphis* sp.*):* These are small, green insects which suck the sap of the plant. They multiply very quickly and cause considerable damage when in large numbers, particularly in the early stage. In full grown plants, the leaves turn yellow and plants loose vigour. Give foliar application of dimethoate (0.2%) if aphid attack is observed.

Mites: (*Tetranychus* sp.) They are the sucking pests. For control of mites, mix neem soap or pongamia soap @ 10 g/L with ethion 50 EC @ 1 ml/litre and spray.

Thrips *(Thrips palmi):* Thrips, like most species of plant feeding thrips, have piercing and rasping mouth parts. The mouth parts are thrust deep into the leaf tissue, sucking out cell contents. The surface of the leaf develops a crinkled silvery appearance as a result of damage to cells below the surface. Lightly-infested plants show silvery feeding scars on the under surface of leaves, especially alongside the mid rib and veins. Heavily-infested plants show silvering and browning of leaves, stunting of young leaves and terminal growth, with fruit scarred and deformed. Developing leaves become distorted in the growing tips. Spray

imidacloprid 17.8 SL @ 0.4 ml/litre or fipronil 50 SC @ 1.5 ml/litre or acephate @ 1.5 g/litre for managing thrips.

***Leaf eating caterpillars** (Diaphania indica):* Symptoms of damage are, young larva scrapes the cholorophyll content; later on it folds and webs the leaves and feeds within; it also feeds on flowers and bores into developing fruits. For leaf eating caterpillar control, collect and destroy early stage caterpillars; spray *Bacillus thuringiensis* preparations @ 1 ml/litre when oviposition is noticed on the leaves; spray contact insecticide carbaryl 50WP @ 3 g/litre or indoxacarb 14.5 SC @ 0.5 ml/litre. Alternatively spray neem or pongarnia soap @ 7.5 g/litre.

Harvesting and yield

Harvesting of watermelons is done when they are mature. In watermelon, usually it takes 45–50 days from the date of pollination for maturity. The maturity of watermelon is judged by the following guide lines:

1. On thumping the fruit with a finger, a ripe melon gives a flat dead sound, where as unripe fruit gives a ringing sound.
2. The colour of the rind which touches the ground (belly) changes from white to light yellow on ripening.
3. The tendril nearest to fruit becomes dry when the fruit is ripe.
4. On putting pressure on the fruit, a ripe watermelon cracks within.

An average yield of 500–800 q/ha can be obtained with well managed crop,

Seed production

Cultural practices followed for the seed production crop are similar to that for fruit production. However, the following aspects are to be considered:

Pollination: Watermelon is monoecious in nature and its fertilization is entomophilous. Sometimes, problem of fruit setting occurs in some part of our country due to the non-availability of insects in early morning during winter-season. In this case, hand-pollination showed some good result in fruit setting. Hand pollination is accomplished by transferring pollen of a new staminate flower to the stigma of a pistillate flower which blossoms on the same day.

Pruning: Pruning and training followed by hand pollination is a good practice for increasing yield of watermelon. When all the vines of watermelon are allowed to grow, they overlap each other and reduce fruit production. Densely growing vines disturb the entomophilous fertilization and excessive vegetative growth also impairs the reproductive stage of the plant. Main vine and three lateral vines growing vigorously at the base of plant are kept and other lateral vines are pruned out. Pruning should not be done after fruit setting and one fruit should be allowed to develop on each vine in order to get good quality of fruits.

Isolation: Watermelons are highly cross-pollinated. The different varieties of watermelon should not be grown together; otherwise these varieties would be contaminated by cross pollination. Fields for open pollinated watermelon seed production should be isolated by at least 800-1000 m from other watermelon fields to prevent contamination by outcrossing.

Roguing: Roguing is done at four stages in watermelon as follows:

1. **Early vegetative stage:** The plants whose vine growth, leaf shape and colour

and resistance to specific pathogens are not in accordance with the cultivar description, should be removed.

2. **At early flowering:** Plants, having under developed fruits on female flower buds whose characters are not true to type, should be removed earlier to prevent the out crossing of surrounding plants by the off type pollen.
3. **Fruit developing:** Developing fruits of such a plant which are not typical of the cultivar, should be removed earlier along with the whole plant.
4. **Marketable fruit:** Fruits, whose skin, colour, size, shape and quality (TSS, flesh colour *etc.*) are not in accordance with cultivar description, should be removed

Fruit harvest for seed: Ripe melons are good for seed extraction. After extraction the seeds may be dried in the sun or mechanical driers may be used. Well matured fruits are harvested for seed extraction. Seed maturity in watermelon coincides with edible maturity and so there is no difference in picking stage. However, it is useful to harvest fruits for seed at least one week later than the optimum stage for marketing. For seed collection, fruits need to be verified for flesh colour and per cent TSS content. The fruits scoring less than 9% TSS should be rejected.

Seed extraction and washing: Before seed extraction fruits should be stored in room temperature for 1–2 weeks preferably in a cooler dry place. Afterward, the fruits are cut into half and pulp with seeds should be scooped out using a knife. Seeds can be separated from pulp and kept for a day for fermentation to take place. Then the seeds are washed with water in troughs.

Seed drying and seed yield: The washed seeds should be dried quickly. For this, trays with screen wire or burlap bottoms may be used. The seeds are spread on trays and placed in the shade and gradually to sun to dry and continued up to a moisture level of 7 per cent. Frequent turning of seeds will ensure uniform drying. Seeds may be dried more rapidly in a drier or dehydrator employing artificial heat and forced air circulation for large quantity. Seed should be dried carefully at a temperature not exceeding 38–42°C. The average seed yield of most watermelon cultivars under good management conditions is about 120–200 kg/ha.

Seed storage: For safe storage, moisture content of the seeds should be 7 per cent. Moisture determinations should be made on properly drawn samples of seed at the temperatures prevailing in the seed storage facility. The well dried seeds are placed in containers and stored in a cool, well ventilated room, preferably provided with some means of dehumidification, and with protection from rats and other pests. Commercial seeds should be treated with a registered protectant such as captan before sealing them into cans, bags, or packets. Seeds should be stored in hermetically sealed containers at 6.5% moisture content, and no greater than 10% moisture. Under favorable storage conditions, seeds should last 4 years. To be salable, germination of the seed lot must be at least 70%. Watermelon seeds will remain viable for five or more years if properly stored.

MUSK MELON

Musk melon is native to the continent of Africa. Many wild forms of melons can still be found there today. Though it is not known when melons were first cultivated, it is believed that prehistoric man may have gathered and saved the seeds of the

Fig. 5. Musk melon

sweetest melons, and this practice led to cultivation. Seeds and wall paintings found in Egyptian tombs indicate that melons were under cultivation in Egypt at least 4,000 years ago. Melons were introduced into Asia about 3,000 years ago. The melon became immensely popular in the region that includes Iran, Iraq, Afghanistan, India, south and central Russia, China and Japan. The Greeks and Romans most likely introduced the melon into Europe. Columbus brought melons to the New World on his second voyage, and by 1494 melons were under cultivation in Haiti. By the 16th century, melons were being cultivated throughout North and South America.

Muskmelons are distinctive for the netting that covers most of their rind, and they are usually ribbed. The melons come in many sizes and shapes including round, oval, and cylindrical. The flesh is generally orange and quite sweet, but some varieties of muskmelon and specifically, the Persian melons, can have green or white flesh. Some green fleshed melons are quite sweet, but most of the green fleshed and white fleshed melons have a less sweet, but very refreshing flavor. In Hindi muskmelon is known as *Kharbuz.*

Most melons are grown in almost all states of India. Muskmelon is grown in an area of 38,000 ha with a production of 791,000 tonnes and productivity of 20.5 tonne/ha, whereas watermelon is grown in an area of 71,000 ha with a production of 1727,000 tonne and productivity of 24.5 tonne/ha (NHB, 2011).

Melons are good sources of carbohydrates, vitamin A and C, and minerals. Musk melon contains 94% of water, 5% of carbohydrates, 1% of protein, 3420 IU of vitamin A, and 33 mg of vitamin C. The fruits are mostly used as dessert.

Botany

Muskmelon (*Cucumis melo* L.) belongs to the family Cucurbitaceae and the genus *Cucumis.* This has a somatic chromose number of 2n=24. They are either vines or creepers. Flowers are monoecious or andromonoecious and are highly cross-pollinated. The fruit is a ‘pepo’ botanically and it varies in shape, size, colour and taste. The leaves are simple, alternate and palmately lobed in musk melon. Tendrils are either simple.

Nearly all textbooks give ‘melon’ as the first or only common name for the species *Cucumis melo* L.. ‘melon’ is really the general name for the species. “The preferred and usual common name for the species *Cucumis melo* is ‘melon’, while musk melons or cantaloupes are a group within the species”. Many monographs and texts follow the groupings or ‘tribes’ of Naudin. These have usually been called ‘botanical varieties’, but Smith and Welch called them ‘groups’, stating that the former term applies only to plants in the wild. The ten tribes of Naudin were reduced to seven groups by Whitaker and Davis. Munger and Robinson

(1991) proposed to simplify the grouping further by combining *cantalupensis* with *reticulatus* and *chito* with *dudaim*. They added a group, for which *momordica* seems to be the accepted name, to include the widely grown snap melon of India. The revision of groups within the species is as follows:

1. ***C. melo agrestis*** Naud. Wild types with slender vines and small, inedible fruit. Probably synonymous with *C. melo callosus* and *C. melo trigonus*.
2. ***C. melon cantalupensis*** Naud. Cantaloupe or muskmelon. Medium size fruits with netted, warty, or scaly surface, flesh usually orange but sometimes green, flavor aromatic or musty. Fruit dehiscent at maturity. Usually andromonoecious.
3. ***C. melo inodorus*** Naud. Winter melons. Smooth or wrinkled surfaces with flesh usually white or green and lacking musky odor. Usually larger, later in maturity, and longer keeping than cantalupensis, and not dehiscent at maturity. Usually andromonoecious.
4. ***C. melo flexuousus*** Naud. Snake melon. Synonym of snake cucumber, a common name causing confusion and therefore to be avoided. Fruit long and slender, used when immature as an alternative to cucumber. Monoecious. *C. melo utilisimus* or long melon described in literature from India is considered by some to be synonymous with flexuosus.
5. ***C. melo* conomon** Mak. Pickling melon, sweet melon. Small fruit with smooth skin, white flesh, early maturity, and usually with little sweetness or odor. However, some melons in this group have high sugar content when mature and are eaten like apples, rind included. Andromonoecious.
6. ***C. melo chito*** and ***C. melo dudaim*** Naud. Mango melon, vine peach and other similar names for the former; pomegranate melon, Queen Anne's Pocket melon for the latter. Distinction between these two groups is not clear from published descriptions.
7. ***C. melo momordica***. 'Phut' or snap melon. Grown in India and other Asian countries and distinct from any other group. Flesh is white or pale orange, low in sugar, and mealy. The smooth surface of the fruit cracks as maturity approaches and the fruit disintegrates when barely ripe. Most melons in this group are monoecious.

Breeding

Choudhary *et al.* (2002) reported that 70 indigenous muskmelon germplasm lines from different geographical pockets/riverbeds were collected, evaluated and characterized morphologically as well as electrophoretically for sustainable global utilization. Luthra and Yadav (2002) reported that MHY 5, a selection from the cross Durgapur Madhu × Hara Madhu, was a high yielding line with an average fruit yield of 150–200 q/ha. It was also found to be moderately resistant to root knot nematode and powdery mildew, resistant to virus and free from downy mildew under field conditions. More (2002) reported sources of resistance to downy mildew and green mottole mosaic virus in *Cucumis* sp. At IIHR, Bengaluru, musk melon varieties, Arka Rajhans, Jacumba, Dulce, PMR 5 and Gulfstream showed field resistance to powdery mildew.

Improved cultivars

Disease resistant cultivars

Punjab hybrid: This hybrid is released by PAU, Ludhiana. Fruits are round with distinct sutures. Rind thick, netted creamish yellow in colour. Flesh thick, orange, juicy, melting, good aroma and sweet. TSS 12–13%. High keeping and transport quality, moderately resistant to powdery mildew and fruit fly. Maturity 75–80 days. Yield 160–170 q/ha.

DMDR 2: This variety is released by IARI, New Delhi. Fruits are oval-round with green stripes, yellowish smooth skin, orange flesh. Average fruit weight 950–1000 g. TSS 11–12%. Resistant to cucumber green mottle mosaic virus (CGMMV) and downy mildew diseases. Maturity 85–90 days. Yield 160 q/ha.

Kashi Madhu: This variety is released by IIVR, Varanasi. Fruits are round. Harvesting starts from 90 days after sowing and continues up to 105 days. Tolerant to powdery mildew, downy mildew and muskmelon mosaic virus. Yield 250 q/ha in 105 days.

Arka Rajhans: This variety is released by IIHR, Bengaluru. An early-medium variety, medium-large oval fruit, weigh 1–1.5 kg. Dirty white, fine nets. Has excellent keeping and transport quality. Flesh thick, white, more sweet, TSS 12 to 14%. Highly resistant to the powdery mildew. Yields 250–300 q/ha. 85–90 days duration.

Other cultivars

Pusa Sharbati: This variety is released by IARI, New Delhi. Fruits are round, straw coloured, netted and striped skin, flesh salmon orange, firm, thick with small seed cavity. TSS 11–12%. Fruits have good keeping quality. Maturity 80–85 days after sowing. Yield 150–170 q/ha.

Pusa Madhuras: This variety is released by IARI, New Delhi. Fruits are flattish round, sparsely netted, yellowish green smooth skin with salmon orange flesh. Very sweet, TSS 12–14%. Maturity 95–100 days. Yield 180–200 q/ha.

Durgapur Madhu: Fruits are oblong, pale green smooth rind, light green flesh with big seed cavity. TSS 12–13%. Maturity 85–90 days. Yield 160 q/ha.

Hara Madhu: This variety is released by HAU, Hisar. Fruits are round, tapering towards the stalk-end with prominent green sutures. Rind thin, smooth, turns pale yellow at maturity. Flesh green, thick, very juicy, melting and sweet. TSS 12–15%. Maturity 110–120 days. Yield 125–150 q/ha.

Pusa Rasraj: This variety is released by IARI, New Delhi. The first monoecious hybrid. Fruits are slightly oval, skin smooth, non-striped, dull white with green and sweet flesh. TSS 11–12%. Maturity 70–75 days. Yield 200–250 q/ha.

Arka Jeet: This variety is released by IIHR, Bengaluru. Fruits are small attractive orange yellow, round, weight 400 to 800 g. Very sweet, TSS 15 to 17% with high vitamin C content (41.6 mg/100 g fresh weight). An improvement over the Lucknow Bati, a local strain of Uttar Pradesh. Yields 140–150 q/ha. Duration 90 days.

Hisar Saras and Hisar Madhu are developed by HAU Hisar whereas Punjab Raseela and Punjab Sunehri are the other varieties released from PAU, Ludhiana.

Climate and soil

Melons normally require a warm and dry weather, good sunshine, low humidity and frost-free period. Duration of crop varies from 85–110 days. Optimum temperature for plant growth varies from 23.90–26.7°C with the minimum and maximum being 18.3 and 32.3°C, respectively. Melons grow best and give heavy yield in a well drained, sandy-loam soil. Heavy soil, if drained well, also gives good yield. Commonly they do not grow well in highly acidic or alkaline soils.

Cultural requirements

Sowing time: Melons are generally grown in summer. Seeds of all melons are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of January for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 2.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 200 cm and between the hills is 75 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (75 kg N, 100 kg P and 75 kg K/ha) in the furrows made in the sowing sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place, where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give alight inigation. Seed rate per hectare is 1.5–2.0 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining two good seedlings in each hill. Top dress the crop with nitrogen (25 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon

Harvesting and yield

Harvesting of muskmelons is done when they are mature. The maturity of musk melon is judged by the following guidelines:

1. In most cases when the fruit is mature it slips out easily from the vine, leaving a circular depression. This is known as the 'full slip' stage.

2. In case of netted muskmelon, the green color between the nets changes to yellow and nets become dirty white.

Maturity of muskmelon is judged by two methods, viz. half slip and full slip stages. In case of half-slip stage, matured fruit is not fully slipping out from the attachment of the fruit but in full-slip stage, matured fruits slip out from the vines easily leaving a circular scar or depression.

An average yield of 150–200 q/ha can be obtained from a well managed crop.

Seed production

Cultural practices followed for the seed production crop are similar to that for fruit production. The aspects to be considered in watermelon seed production are to considered for muskmelon also.

Muskmelon, snap melon, and long melon are highly cross compatible with each other. The different varieties of any one of the melons mentioned above should not be grown together; otherwise these varieties would be contaminated by cross-pollination. The recommended isolation distance for seed production is about 800–1,000 m.

Proper rouging is very necessary. Mature fruits of muskmelon tend to separate from the stem at the base of the fruit by formation of an abscission layer. This is usually referred to as 'full-slip' stage. For large scale seed production melons are harvested at full-slip stage, fermentation is not required. The seeds are washed in water and dried in the sun or mechanical driers may be used. Seed should be stored at 2–5°C and 40% relative humidity condition for prolonged viability. For vapour proof storage moisture content of seeds should be six percent. Melon seeds can be kept for up to five years if properly stored. A seed yield of 200–250 kg/ha can be obtained.

SNAP MELON

Snap melon is distributed in the tropical and subtropical parts of the world. It is cultivated throughout India and Pakistan and in the Southern parts of India such as Tamil Nadu and Karnataka. Snap melons are Asian melons not grown in the United States.

This creeper is mainly grown for its fruits which are used as vegetable and salads. They come in a variety of shapes and sizes, but their flesh is almost universally white fading to a pale green or a pale orange. What is unusual about this class of melons is that their flesh is as fluffy as snow. The flesh is not sweet. These melons are popular in Asia and eaten as a vegetable not as a fruit. In India the young tender fruits are eaten raw or cooked, and the ripe fruits are eaten as a dessert. The fruits explode when mature, scattering their seeds and giving them the name 'snap' melon. The young fruit is used as a substitute for the cucumber or cooked as vegetable. Although it is inferior to the melon, the fruit is eaten on ripening. Fruits oval or cylindrical, smooth, yellow in colour, often spotted with dark green, when ripe bursts spontaneously, varies in size from 30–60 cm × 7–15 cm. The young fruits resemble the cucumber. The flesh is mealy and insipid. It is also called as *phut* or *phoot* in Hindi.

Botany

Snap melon (*Cucumis melo* var. *momordica*) belongs to the family Cucurbitaceae and the genus *Cucumis.* Snap melon is an annual creeper having lobed leaves. The leaves are simple, alternate and palmately lobed. Tendrils are simple. The plant bears unisexual flowers and a fleshy fruit with many seeds. They are monoecious and highly cross-pollinated. The fruit is a 'pepo' botanically and it varies in shape, size, colour and taste.

Climate and soil

Melons normally require a warm and dry weather, good sunshine, low humidity and frost-free period. Duration of crop varies from 85–110 days. Optimum temperature for plant growth varies from 23.90–26.7°C with the minimum and maximum being 18.3 and 32.3°C, respectively. Melons grow best and give heavy yield in a well drained, sandy-loam soil. Heavy soil, if drained well, also gives good yield. Commonly they do not grow well in highly acidic or alkaline soils.

Cultivars

Pusa Shandar: This is released by IARI, New Delhi. Fruits oblong, medium in size with creamy white skin, thick and light pink flesh. Average yield 380 q/ha. Maturity 45–50 days.

AHS- 10: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. Fruits can be harvested 68 days after sowing, which are oblong and medium in size (900 g). Flesh whitish pink, sweet in taste having 4.5–5.0% TSS. Bears 4–5 fruits per vine giving an yield of 230 q/ha under arid conditions.

AHS- 82: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. Fruit harvest starts 67–70 days after sowing. Each vine bears 4–5 fruits giving an yield of 250 q/ha. The flesh is light pink, sweet having 4.3–4.9% TSS.

There are many local varieties which are being grown in different parts of India.

Cultural requirements

Sowing time: Melons are generally grown in summer, but snap melon are grown in rainy-season also. Seeds of all melons are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of January for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonnes/ha of FYM at the time of ploughing. Open up 2.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 200 cm and between the hills is 75 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the

ridges with the help of a pick axe. Apply the fertilizer mixture (75 kg N, 100 kg P and 75 kg K/ha) in the furrows made in the sowing sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give alight irrigation. Seed rate per hectare is 1.5– 2.0 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining two good seedlings in each hill. Top dress the crop with 25 kg N/ha, 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

Harvesting of snap melons is done when they are mature. In case of snap melon the green rind turns yellow or orange at full maturity. An yield of 170- 185 q/ha can be obtained.

Seed production

Cultural practices followed for the seed production crop are similar to that for frruit production. Follow the guidelines as given for musk melon for seed production.

Snap melon, muskmelon, and long melon are highly cross compatible with each other. The different varieties of any one of the melons mentioned above should not be grown together; otherwise these varieties would be contaminated by cross pollination. The recommended isolation distance for seed production is about 800 m. Proper rouging is very necessary. Ripe melons are good for seed extraction. After extraction the seeds may be dried in the sun or mechanical driers may be used. Seed should be stored at 2–5°C and 40% relative humidity condition for prolonged viability. For vapour proof storage moisture content of seeds should be 6%.

LONG MELON

Long melon is an herbaceous plant having monoecious flowers. Leaves are alternate and lobed. The plant bears a fleshy fruit for which it is cultivated. The fruits are used to make vegetable. It occurs in tropical and sub-tropical parts of the world. The common names of long melon are, snake cucumber, serpent melon, *kamal kakri and kakri.*

Long melon is valued for tender fruits which are eaten raw along with salt and pepper. Due to its cooling effect this is very popular during summer

months in most part of the country. If it is taken without salt, it is not easily digested. Similarly, drinking of water immediately after eating fruits causes indigestion.

The fruits are mostly used as dessert, as ingredients of salad and as vegetable. For pickling, fruits are harvested when full size but still immature. The seed cavity is removed and only the rind used in making of pickles. The fruits are used as summer squash in various ethnic dishes.

Botany

Long melon [Cucumis melo var. flexuosus Naud.; syn: *Cucumis melo* var. *utilissimus* Duthie & Fuller] belongs to the family Cucurbitaceae and the genus *Cucumis.* They are either vines or creepers. Flowers are monoecious and are highly cross pollinated. The fruit is a 'pepo' botanically and it varies in shape, size, colour and taste. The leaves are simple, alternate and palmately lobed. Tendrils are simple. The somatic chromose numbers of long melon is 2n=24.

Floral biology: Plants are monoecious in nature. Corolla is showy, yellow in colour. Petals are 5 in number, united, stamens are attached to calyx tubes. Ovary is inferior. The period of bud developmental stage is completed within 12–15 days in male and within 11–13 days in female bud.

Improved cultivars

Arka Sheetal: This variety is released by IIHR, Bengaluru. Fruit medium long light green skin, shallow furrows, fruit weight 80–90 g. Flesh crisp, excellent flavor. Yield 350 q/ha. Duration 100–110 days. A selection from the local strains of Lucknow. Recommended for Karnataka.

Karnal Selection: This variety is released by HAU, Hisar. A prolific bearer, fruits tender, light green, long, thin; flesh crisp with good flavour. Fruit yield 90–100 q/ha.

Punjab Long melon-1: This variety is released by PAU, Ludhiana. Early, fruit cylindrical long and light green.

Climate and soil

Long melon normally requires a warm and dry-weather, good sunshine, low humidity and frost-free period. Duration of crop varies from 85–110 days. Optimum temperature for plant growth varies from 23.90–26.7°C with the minimum and maximum being 18.3 and 32.3°C, respectively. Long melon grows best and give heavy yield in a well drained, sandy-loam soil. Heavy soil, if drained well, also gives good yield. Commonly they do not grow well in highly acidic or alkaline soils.

Cultural requirements

Sowing time: Melons are generally grown in summer. Seeds of all melons are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of January for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 2.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 2.0–2.5 m and between the hills is 75 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (40 kg N, 60 kg P, 40 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds per hill and cover them with soil and give alight irrigation. Seed rate/hectare is 1.5–2.0 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top-dress the crop with nitrogen (20 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

Harvesting of long melons is done when they are immature and tender. The fruits of long melon are picked when they are still tender, about one third or one fourth their full size. The fruits do not keep well for more than one day, so they should be disposed of promptly. The yield of long melon is about 350–400q/ha.

Seed production

Cultural practices followed for the seed production crop are similar to that for vegetable production. Follow the guidelines as given for musk melon for seed production. A seed yield of 150–200 kg/ha can be obtained.

ROUND MELON

The origin of round melon is probably western India, where wild types may still be found in the wild. It is cultivated in Pakistan and Afghanistan as a vegetable. In Punjab, Uttar Pradesh, Rajasthan and Mumbai it is quite important as a cultivated market vegetable. The Hindi name *tinda* is commonly used in other parts of the world. It also called as Indian round gourd or apple gourd or Indian Baby Pumpkin. It is a squash like cucurbit grown for its immature fruit, a vegetable especially

Fig. 5a. Round melon

popular in South Asia. "*Tinda*" is also called as "*tindsi*" in Rajasthan. *Tinda* is a famous nickname among Punjabi families. The tender immature fruits are used as a cooked vegetable.

Botany

Round melon [*Praecitrullus fistulosus* (Stocks) Pangalo; syn. *Citrullus vulgaris* var. *fistulosus* (Stocks); *Colosynthis citrullus* var. *fistulosus* (Stocks)] belongs to the family Cucurbitaceae and is the only member of the genus *Praecitrullus.* The plant is a prolific vine, and is grown as an annual. The fruit is approximately spherical, and 5–8 cm in diameter. The seeds may also be roasted and eaten. Green colored, apple sized fruits are flattish round in shape and 50–60 g in weight. Plants are vigorous, productive and begin to bear fruits in 70 days after planting.

The plant is, as with all cucurbits, a prolific vine, and is grown as an annual. Flowers are monoecious or andromonoecious and are highly cross-pollinated. The fruit is a 'pepo' botanically. In round melon, the leaves are cordate at the base and deeply pinnated into 3 or 4 pairs of lobes. Tendrils are branched. The fruit is approximately spherical, and 5–8 cm in diameter. Plants are vigorous, productive and begin to bear fruits in 70 days after planting. The somatic chromosome number of round melon is 2n = 22.

Most of the Indian authors considered round melon (*tinda*) as a variety of watermelon. However, on the basis of morphological characters, geographical distribution and cross compatibility, it was suggested that round melon should be placed in the genus *Cucumis.* On the basis of poor crossability of round melon with either watermelon or muskmelon, as well as its complete incompatibility with long melon and snap melon, it was suggested that round melon be placed in a separate genus *Praecitrullus* (Nath *et al.* 2002).

Improved cultivars

Arka Tinda: Developed at IIHR, Bengaluru. Recommended for Karnataka and grown in northern states. An early summer variety; fruits round, light green with soft hairs, tender flesh at marketable stage. Maturity 90–100 days. Yield 95–100 q/ha.

Punjab Tinda: Developed at PAU, Ludhiana. Fruits medium in size, flat round and light green. Fruit surface shining and pubescent. Flesh white, less seedy, tender, good cooking quality. Maturity 60 days. Yield 45 q/ha.

Bikaner Green: Fruits round, tender and green in colour. Suitable as spring–summer crop in Rajasthan.

Hissar Selection-1: Developed at HAU. Fruits oval, green in colour with hairs, very attractive.

Annamalai Tinda: Released by Annamalai University, Tamil Nadu.

Climate and soil

Round melons are generally grown in summer, but round melon is grown in rainy season also. In case of round melon, varieties suitable for summer season do not grow well in rainy season and vice-versa. Round melon normally requires a warm and dry-weather, good sunshine, low humidity and frost-free period. Duration of crop varies from 85 to 110 days. Optimum temperature for plant growth varies from 23.9°–26.7°C with the minimum and maximum being 18.3 and 32.3°C, respectively. It grows best and give heavy yield in a well drained, sandy-loam soil. Heavy soil, if drained well, also gives good yield. Commonly they do not grow well in highly acidic or alkaline soils.

Cultural requirements

Sowing time: Round melons are generally grown in summer. Seeds are sown directly in the field as they cannot withstand transplanting well. In the plains, sowing is done from November to middle of January for the summer crop. However, middle of February is the best time for most of the northern states while December-January is the best time for most of the southern states.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 3.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges or bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 2.0–2.5 m and between the hills is 75 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (40 kg N, 60 kg P, 40 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give alight irrigation. Seed rate/ha is 3.0–3.5 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (20 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon

Harvesting and yield

Harvesting of round melons is done when they are immature and tender. The tender fruits, as long as they retain their luster of the rind, should be harvested. As soon as it fades, the rind starts becoming hard and the fruit quality is reduced. Harvesting should be done at an interval of 4–5 days. The fruit can be harvested after 5–6 days of pollination. The yield of round melon is about 75–100 q/ha.

Seed production

Cultural practices followed for the seed production crop are similar to that for vegetable production. Follow the guidelines as given for watermelon seed production.

Round melon is highly cross-pollinated. The different varieties of round melon should not be grown together; otherwise these varieties would be contaminated by cross-pollination. The recommended isolation distance for seed production is about 800–1000 m. Proper rouging is very necessary.

Harvesting fruits and seed extraction: Ripe round melon fruits are good for seed extraction. The selected fruits confirming to the genetic characters alone should be used for seed extraction. First the fruits are cut into two halves. Then the seeds along with pulp are crushed with hand in excess quantity of water. Then the floating fraction is removed and the seeds settled at the bottom are collected. The collected seeds should be properly washed with the clean water.

The extracted seeds should be spread on gunny bags in a thin layer and dried under shade for 8 to 10 hours for 1 or 2 days. Then, seeds can be dried under direct sunlight between 8 AM to 12 noon and 3–5 PM. Avoid drying in between 12 noon to 3 PM, since the rays emitted from sun and the heat may affect the seed viability. The extracted seed should not be dried directly under sun. Since seed posses high moisture it may affect the germination potential. Similarly, while drying frequent stirring is more important otherwise, it leads to clogging. This may results in improper drying, fungal growth and poor vigour. Hence, even if the seed is dried to safe moisture, but stored in a humid climate, then seed gains moisture during storage and looses vigour. Seed should be stored at 2–5^0 C and 40% relative humidity condition for prolonged viability. For vapour proof storage moisture content of seeds should be 6% (Dilip Parmar, 2012). A seed yield of 200–250 kg/ha can be obtained.

CUCUMBER

Fig. 6. Cucumber

The cucumber is originally from India but is now grown on most continents. In Hindi cucumber is known as *khira* or *kheera*. The area under cucumber in India is 40,000 ha with a production of 6,07,000 tonne and productivity of 15.3 tonnes/ha (NHB, 2011). It is one of the most popular summer vegetable crops. It is chiefly grown for its edible tender fruits preferred as

salad ingredient, pickles, desert fruit and as cooked vegetables. It is very much useful for preventing, constipation and beneficial for people suffering from jaundice and allied disease.

Botany

The cucumber (*Cucumis sativus*) is a widely cultivated plant in the family Cucurbitaceae. It is a creeping vine which bears cylindrical edible fruit. There are three main varieties of cucumber: 'slicing', 'pickling', and 'burpless'. The cucumber is a creeping vine that roots in the ground and grows up trellises or other supporting frames, wrapping around supports with thin, spiraling tendrils. The plant has large leaves that form a canopy over the fruit. The fruit of the cucumber is roughly cylindrical, elongated with tapered ends, and may be as large as 60 cm long and 10 cm in diameter. Having an enclosed seed and developing from a flower, botanically speaking, cucumbers are classified as accessory fruits. Much like tomatoes and squash they are often also perceived, prepared and eaten as vegetables. Cucumbers are usually more than 90% water.

A few varieties of cucumber are parthenocarpic, the blossoms creating seedless fruits without pollination. Pollination for these varieties degrades the quality. These are usually grown in greenhouses, where bees are excluded. Most cucumber varieties, however, are seeded and require pollination. Symptoms of inadequate pollination include fruit abortion and misshapen fruit. Partially pollinated flowers may develop fruit which are green and develop normally near the stem end, but pale yellow and withered at the blossom end. Traditional varieties produce male blossoms first, then female, in about equivalent numbers. New gynoecious hybrid cultivars produce almost all female blossoms. However, since these varieties do not provide pollen, they must have a pollenizer variety interplanted.

Breeding

Krishna Prasad *et al.* (2002) reported the development of new slicing cucumber cv. 'Swarna Ageti' through genetic architecture. Biparental mating followed by reciprocal recurrent selection helped to increase the frequency of genetic recombinations and hasten the rate of genetic improvement in selected populations. After attaining homozygosity, two advanced breeding lines were identified as 'Swarna Sheetal' and 'Swarna Ageti' performed exceedingly well in different agro climatic conditions of India.

Improved cultivars

Disease resistant cultivars

Pusa Barkha: This is released by IARI, New Delhi. First extra early improved variety of cucumber for *kharif* season cultivation for north Indian plains. Field tolerant to high humidity, high temperature and downy mildew disease. Average fruit yield 188 q/ha during *kharif* season.

Poinsett: Fruits are dark green and 20–25 cm long. It is resistant to downy mildew, powdery mildew, anthracnose and angular leaf-spot. Suitable for summer

season. Maturity 40–50 days. Yield 180 q/ha.

Swarna Poorna: Released by ICAR-RCER, Patna, Bihar. It is tolerant to powdery mildew. It gives an yield of 200–300 q/ha.

Swarna Ageti: Released by ICAR-RCER, Patna, Bihar. It is tolerant to powdery mildew. It gives an yield of 300–325 q/ha.

Swarna Sheetal: Released by ICAR-RCER, Patna, Bihar. It is tolerant to powdery mildew. It gives an yield of 200–300 q/ha.

Other cultivars

Pusa Uday: Developed at IARI, New Delhi. Early, 13–15 cm long, light green, non-wrinckled, suitable for both spring-summer and rainy season. Maturity 48–52 days. Yield 140–155 q/ha.

Pusa Sanyog (F1): Developed at IARI, New Delhi. Very early, fruits 28–30 cm long, cylindrical, attractive, very heavy yielder. It gives an yield of 200 q/ha. Fruits mature in 50 days. It performs well in temperate regions only.

Japanese Long Green: A temperate cultivar, is suited for cultivation in hills and lower hills. Its extra early fruits mature in 45 days. Fruits are 30–40 cm long, with light green and crisp pulp.

Poona Khira: Fruits are small sized and pale green. It is popular in Maharashtra and border districts of Karnataka and Andhra Pradesh.

Sheetal: This variety is recommended for commercial cultivation in Konkan region.

Himangi: It is a recently recommended variety.

Climate and soil

The plants prefer a warm climate and do well in areas with 30°C temperature during day and 18–24°C at night. Below 15°C and above 35°C temperature do harm to the natural plant growth and thereby reduce the yield. It can be grown in both summer and rainy seasons, but it cannot tolerate cold injury. An abundance of light gives rise to male flowers though within limits. Similarly higher temperature and long-days will increase the number of male flowers and reduce the number of female flowers. Silty loam and clay loam soil with a *p*H value of 6.5 or slightly above containing sufficient organic matter are most suitable for its successful production though it can be grown also in sandy or sandy loam soil.

Cultural requirements

Sowi time: Cucumber is grown both in summer and rainy seasons. Rainy season crop is more successful than the summer season crop. In the plains, summer season crop is grown from January-March, whereas rainy season crop is sown in June-July. In hot areas of Rajasthan, the summer crop of cucumber is not encouraged. In frost-free areas, sowing is done in October, which gives the earliest crop in March (Nath *et al.* 2002).

In southern and central India, it is sown in October-November In plains of northeastern India, sowing time is from November to March when weather is comparatively dry. In Maharashtra, it should be sown in January-February (summer crop) and June-July (rainy season crop). In hills, its sowing time is April-May.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 3.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 2.0–2.5 m and between the hills is 75 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (30 kg N, 50 kg P, 50 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds per hill and cover them with soil and give a light irrigation. Generally soaking of seeds in water or carbendazim 50 WP (0.1%) solution for a few hours before sowing enhances germination. Seed rate per hectare is 2.5–3.0 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (30 kg/ha), 40 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot. Generally vines are allowed to trail on the ground. Vines are generally not trained when cucumber is grown commercially. However, staking of plants particularly in rainy season, is helpful in checking the rotting of fruits.

Pest and disease management

Follow the spray schedule as given for watermelon

Harvesting and yield

Unlike other cucurbits, the proper stage of fruit maturity in cucumber is judged by the size and not by the age of the fruit. Cucumber for slicing should be picked when the fruits are 15–35 cm long, whereas for pickling they should be harvested when 6–15 cm long. In case of slices, it should be harvested, at the marketable stage when spines on the fruit become soft and fall off. Picking of fruits at right stage depends upon individual varieties and marketing requirement. In salad or slicing cucumber, dark green skin colour should not turn brownish yellow or russeting. White spine colour is also a useful indication for their edible maturity. The cucumber should be picked at 2–3 days intervals. Generally cucumber yields about 150–200 q/ha.

Seed production

Cultural practices followed for the seed production crop are similar to that for vegetable production. However, the following aspects are to be considered:

Isolation: To maintain genetic purity of the seed, the recommended isolation

distance between seed crops of different cultivars of cucumber is 800–1000 m for foundation seed and 400–500 m for certified seed. Crops for basic seed production should be isolated by at least 1500 m.

Roguing: Roguing is done at 4 stages in cucumber as follows:

1. **Before 1st flowers open:** At this stage roguing should be done considering growth habit, vigour and foliage typical of the cultivar.
2. **Early flowering:** Roguing is done on the basis of observable characters of under-developed fruit, especially colour of spines and whether any specific seed borne diseases are present.
3. **Fruit setting:** Off types are rogued out considering the following factors such as **(a)** satisfactory level of productivity, (b) fruit characters, including size, shape and colour.
4. **Ripe fruit:** Off types are rogued out considering the colour of ripe fruits in accordance with cultivar description, *e.g.,* fruits either green, yellow, white and orange.

Fruit harvest for seeds: Any malformed or deformed fruits should be removed earlier and only healthy fruits are selected for seeds. The fruits are allowed to ripen fully. The following factors are taken into consideration to judge full maturity in cucumber:

1. Yellow or brown or brownish yellow or russetting skin colour of fruit.
2. Carpel separation in transverse section of fruit.
3. Fruit stalk adjacent to the fruit withers.
4. Mature seeds separate easily from the interior flesh.

After full maturity fruits are harvested and kept by spreading in one single layer with a space between fruits in a shady dry place for 5–7 days for post harvest maturity.

Seed extraction and storage: Fully mature fruits with ripe rind colour are harvested. Mature seeds easily separate from the interior. For seed extraction by hand the fruits are cut longitudinally and the seeds are scrapped into a container where the seeds and juice mixture are allowed to ferment for a day. Seeds are washed in water and dried under sun. Drying is continued until seed moisture reaches to about 10%. Seed should be stored at 2–5°C and 40% relative humidity condition for prolonged viability. For vapour proof storage moisture content of seeds should be 6%. Cucumber seeds are long lasting and may remain viable for as long as 10 years under good conditions.

The seed yield varies from 300–400 kg/ha depending upon cultivar, extent of pollination and cultural management.

GHERKIN

Gherkin (*Cucumis sativus* var. *anguria*) is closely related to cucumber and is extensively consumed by European countries for pickling. The market is expanding with demand increasing in USA and Australia. India has been identified as one of the potential countries which can produce gherkin in large quantities due to favourable climatic conditions prevailing in many important centres. Karnataka is one of the leading states for export of gherkin. But the harvest of fruits requires more care. The young, tender fruits are graded as 'super grade' and best suited for use in vegetable processing, preservation and pickling industry. Colour, texture,

fleshy crisp are the other quality parameters.

Hybrids like Calypso are preferred by the European markets. However, other imported varieties/hybrids, viz., Venlo pickling, NCVH-32, NCVH-35 and NCVH-41 are also popular. Presently no Indian breed varieties are available.

Gherkin cultivation is similar to traditional cucumber cultivation. A well drained loamy soil with *p*H of 6.0–7.0 and a short growing season with a mild-warm climate is ideal for gherkin cultivation.

Harvesting and yield

Gherkin fruits are ready for the harvest between 30th and 35th day. In winter, since the plant growth is slow it may result in 2–5 days delay. Since the western countries which import gherkin in the canned stage specify the grade as the smallest size, the harvesting is a very important operation in gherkin cultivation. S_1 (smallest sized fruit about 250 fruits/kg) fetches the highest price in the market. To obtain this grade, the fruits should be harvested between 4th and 5th day of the anthesis or pollination. If one day is exceeded, the fruits grow to next grade, the harvesting fruits should be done on every day. A day's break would end up with outsized or over-grown gherkin means loss to farmer. The care to be taken while harvesting the fruits are as under:

1. To avoid sharp sun and high temperature, picking of fruits must be done in the very early morning or late evening;
2. Harvested fruits must be collected under shade on a clean surface;
3. While harvesting, the fruits must be separated from the fruit stalk on the plant;
4. The flower head is to be removed from the fruit;
5. Water should not be sprinkled on the harvested gherkin fruits at any stage; Even if there is surface water during harvest, it should be dried by aeration.
6. For collection of fruits jute bags is preferred. The harvested produce must reach the factory on the same day before dusk. Leaving the gherkin unprocessed overnight would result in poor quality product.

Shelf-life of the fruit is better without surface water, kept under dry but cool condition. During transportation, open ventilation for aeration is recommended but the vegetable must not be exposed to rain and extreme weather.

PUMPKIN

Fig. 7. *Sita fal*

The origins of the pumpkin can be traced to the southern regions of North America and the Northern regions of South America. Mature and immature fruit of the pumpkin are generally edible. In Hindi pumpkin is known as *Sitaphal/ Kaddu*;

All pumpkins have a wide adaptability and are grown in almost all the states of India. In India

presently the area under pumpkins is 11,000 ha with a production of 278,000 tonne and productivity of 25.3 tonne/ha;

Fruits of pumpkins are cooked as vegetable. They are used as sweets and in musical instruments. These cucurbits are good sources of carbohydrates, vitamin A and C, and minerals. 100 g edible portion of pumpkin contains 92.5% water, 0.6% mineral matter, 1.4% protein, 4.6% carbohydrates and 0.1% fat. Cucumber has 96% water but less of carbohydrates than in pumpkin (2.7%).

Botany

Pumpkins (*Cucurbita* spp.) belong to the family Cucurbitaceae and the genus *Cucurbita*. *Cucurbita* is a genus in the gourd family Cucurbitaceae first cultivated in the Andes and Mesoamerica and now used in many parts of the world. Botanically pumpkins and squash are quite similar since varieties of both can be found in *Cucurbita pepo*, and *C. moschata* species. *C. maxima* is also a species of pumpkin generally associated with the larger pumpkins. It includes species grown for their fruit and edible seeds (the squashes, pumpkins and marrows, and the chilacayote), as well as some species grown only as gourds. These gourds (and other squashes) come in many colors. *Cucurbita* species are often used as food, either for their fruit or the seeds lying within. The winter varieties have thick, inedible skins, and so store well. They are also very sweet. Summer squash, on the other hand, have a very thin skin, which can be eaten. The seeds inside can be ground into a flour or meal, roasted and eaten whole, made into pumpkin seed oil, or otherwise prepared. The three important cultivated species are *C. maxima* – winter squash, pumpkin; *C. moschata* – butternut squash, 'Dickinson' pumpkin; and *C.pepo* – acorn squash, field pumpkin, yellow summer squash, zucchini, small multi-colored gourds.

Pumpkin leaves are five lobed, simple, nonhirsute and soft textured, tendril is branched; flowers are mostly monoecious; fruit is a 'pepo' and varies in shape, colour, flavour and taste.

Breeding

Breeding techniques in Cucurbitaceous crops have been discussed and the breeding work done for quality, yield and resistance to disease and insect pests have been reviewed. Some of the genetic materials have been profitably used and some excellent varieties have been developed in pumpkin (Arka Suryamukhi), summer squash (Patty Pan and Early Yellow Prolific). The pumpkin variety Arka Suryamukhi is reported to be the first variety resistant to common fruit fly, *Dacus cucurbitae*. Through careful selection new varieties were obtained in pumpkin (Arka Chandan) with high carotene content and yield (Nath *et al.* 2002). Sirohi (2000b) reported that a new pumpkin hybrid, viz. 'Pusa Hybrid' which is quite suited for cultivation in Punjab, Kerala, Delhi and some parts of northern India. It gives 30% higher yield than the cultivar 'Pusa Vishwas'. Its fruits may be harvested 100 days after sowing. The average yield is 520 q/ha. Pandey *et al.* (2002b) evaluated F_1 hybrids of pumpkin along with parents. Among the evaluated hybrids, PKH 1 was the most promising hybrid in terms of yield, average fruit weight, length of fruit, flesh thickness and β-Carotene.

Improved cultivars

Pusa Vishwas: Developed at IARI, New Delhi. Fruits are spherical and medium in size. Average fruit weight 5.0 kg, fruit flesh thick and golden yellow in color. Recommended for growing in northern plains of India, western Himalayan region, sub-humid, Sutlej-Ganga alluvial plains, sub-humid to humid eastern and southeastern uplands and humid to semi-arid western ghats of Karnataka plateau of the country. Duration of the crop is 120 days after sowing. Yield 400 q/ha.

Pusa Vikas: Developed at IARI, New Delhi. Fruits are small and round flat. Average fruit weight 2.0 kg. Fruit flesh deep yellow. Plant type dwarf (average length 2.0 m). Duration is 110 days. Yield 250–300 q/ha.

***Arka Suryamukhi** (C. maxima):* Developed at IIHR, Bengaluru. Fruit small, economy sized (1 kg), round with flat ends, rind color deep orange yellow, with discontinuous thin cream lining along with shallow furrows. Linings originate from the blossom end, whereas the furrows originate from the stem end. Has excellent flavour, firm texture, bright orange flesh colour and rich in vitamin C. Highly resistant to fruit fly, bears 8–10 fruits per plant. Yield 335 q/ha and the crop lasts for about 115 days.

Arka Chandan (C. moschata Duch): Developed at IIHR, Bengaluru. Fruit medium sized (2.5–3.5 kg), round with slightly poles, rind colour light brown with creamy patches at maturity. Has an excellent flavour, firm texture, and bright orange flesh which is rich in carotene. Bears 2–3 fruits/plant. Yield 325 q/ha. Duration 115–130 days.

Co-1 (C. moschata Duch): Developed at TNAU, Coimbatore. A late variety, matures in 175 days; fruits attractive, globular, medium large (7–8 kg); each vine produces 7–9 fruits; yield 288 q/ha.

Co-2 (C.moschata Duch): Developed at TNAU, Coimbatore. Fruit is of small size, weighing 2 kg. The flesh colour is orange. Yield 226 q/ha.

Kashi Harit: Developed at IIVR, Varanasi. Short vines, fruits are spherical, green, weigh 2.5–3 kg at green stage; 5 pickings can be taken in 70–75 days. It gives an yield of 360–400 q/ha.

Pusa Hybrid-1: Developed at IARI, New Delhi. Fruits are round flat and medium in size. Fruits flesh is thick, golden yellow in color and rich in vitamin A. Average fruit weight is 5.0 kg. Duration is 110 days. Yield 500 q/ha.

Climate and soil

The areas having long period (at least 160 days) with warm, abundance sunshine and low humidity are ideal for successful production of seeds of this crop. It grows best at 18–20°C but can't withstand at minimum 15°C and maximum 45°C. It is more sensitive to fluctuations in light and temperature than other important cucurbits. An abundance of light gives rise to male flowers though within limits. Similarly higher temperature and long-days help the increase in number of male flowers and reduce the number of female flowers. Crop of rainy season is more successful than the summer crop in pumpkin. Soil containing an abundance of humus, or an abundant supply of organic matter, are considered the most desirable for the culture of pumpkin. The best results being obtained on soils which are

near neutral or slightly alkaline. However, loamy soil rich in organic matter with a *p*H value of 5.5–6.8 is the best for successful production of pumpkin.

Cultural requirements

Sowing time: Pumpkin is grown both in summer and rainy seasons. In the plains, summer-season crop is grown from January to March, whereas rainy-season crop is sown in June-July. In hot areas of Rajasthan, the summer crop of pumpkin is not encouraged. In frost-free areas sowing is done in October, which gives earliest crop in March. Generally, the vines are allowed to trail on the ground.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of farmyard manure at the time of ploughing. Open up 3.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 3.0–3.5 m and between the hills is 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (50 kg N, 100 kg P, 50 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give a light irrigation. Generally soaking of seeds in water or carbendazim 50 WP (0.1%) solution for a few hours before sowing enhances germination. Seed rate per hectare is 4.0–5.0 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (50 kg/ha), 40 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot. Generally vines are allowed to trail on the ground..

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

Pumpkin fruits are harvested at full stage of maturity. In most of the cases the fruit stalk becomes dry and the fruit colour changes to yellow or orange yellow at full maturity. An yield of about 300–350 q/ha can be obtained in about 120 days.

Seed Production

Cultural practices followed for the seed production crop are similar to that for vegetable production. However, the following aspects are to be considered:

Isolation: Most of the pumpkin varieties belong to the genus *Cucurbita* and

species *C. moschata* and *C. maxima* may cross with each other. The producer therefore, must know the species to which his varieties belong and should keep the standard isolation distance. To maintain genetic purity of the seed, the recommended isolation distance between seed crops of different cultivars of the same species is 800–1000 m for foundation seed and 400–500 m for certified seed. Crops for basic seed production should be isolated by at least 1500 m.

Roguing: It is done at 4 stages in pumpkin as follows:

1. **Early vegetative stage:** The plants whose vegetative characters (e.g. bush or trailing type), foliage and vigour and resistance to specific pathogens are not in accordance with the cultivar description, should be removed.
2. **Before first flower open:** Plants having under developed fruit or female flower buds, whose characters are not true to type, should be removed.
3. **First fruit setting:** Developing fruits of such a plant which are not typical of the cultivar should be removed alongwith the whole plant itself.
4. **Ripe fruit:** Off-types are rogued out considering the colour of ripe fruits in accordance with cultivar description.

Harvesting of fruit for seed extraction: Pumpkin and squashes usually take 4 months from anthesis to seed maturity. At this stage the rind is hardened and there is change in colour. The immature green fruit turn to a yellow orange colour and yellow golden types change to a straw colour. For seed extraction, fruits should be harvested at full maturity. Maturity of pumpkin fruits can be judged by the following factors:

1. Fruit colour changes to yellow or yellow orange or straw colour.
2. The peduncle becomes straw coloured.
3. The vines start drying.

Any deformed fruit should be removed earlier.

Seed extraction and washing: Before seed extraction fruits should be stored in room temperature for 4–7 weeks spreading in one single layer with a space between the fruits preferably in a cooler dry place. Afterward, the fruits are cut into half and seeds are scooped out by hand. Some placenta may remain with the seeds which are to be separated by rolling and raking simultaneously. After extraction the seeds are washed in water without fermentation as fermentation tends to discolour the seeds and may reduce germination.

Seed drying and seed yield: The washed seeds should be dried quickly. For this, trays with screen wire or burlap bottoms may be used. The seeds are spread on trays and placed in the shade and gradually to sun to dry and continued up to a moisture level of 7%. Frequent turning of seeds will ensure uniform drying. Seeds may be dried more rapidly in a drier or dehydrator employing artificial heat and forced air circulation for large quantity. Seed should be dried carefully at a temperature not exceeding 38–42°C.

For safe storage, moisture content of the seeds should be 7%. Moisture determinations should be made on properly drawn samples of seed at the temperatures prevailing in the seed storage facility. The well dried seeds are placed in containers and stored in a cool, well-ventilated room, preferably provided with some means of dehumidification, and with protection from rats and other pests. For retail sale, tin can with moisture resistant polytheylene or aluminium foil as

wrap or liner can be used. Pumpkin seeds will keep for 5 or more years if properly stored.

The seed yield varies from 400–500 kg/ha depending upon the cultivar, pollination and cultural managements.

SUMMER SQUASH

Summer squash (*Cucurbita pepo* L.) is a quick growing and early yielding cucurbit which is cultivated throughout India. But less preferred than pumpkin and other gourds. It is also known as bush squash, vegetable marrow. Summer squash is mostly annual bush or some time vine. Plants produce stem with greatly shortened internodes and set fruits in close succession. The fruits are picked before the seeds and skin of fruit harden, and used as vegetable. Generally the fruits are ready for picking in about 6 weeks and are picked tender within a few days after pollination. It is stout hispid annual with orbicular, shallow/deeply lobed leaves with petioles covered with prickly hairs. The fruits are of different shapes and colour; seeds are small, numerous, tan to dingy white in colour which are easily separable from pulp. Seed margin is smooth, obtuse and testa is absent in certain cultivars. Squashes are mostly monoecious, but occurrence of an androecious mutant in *C. pepo* is reported. Summer squash is known as *Vilayati kaddu/Chappan Kaddu/Safed kaddu.*

Improved cultivars

Punjab Chappan Kaddu: Developed by PAU, Ludhiana. It is inbred selection from the segregating local variety of Punjab. Plants are bush-type, foliage thick and erect leaves non-lobed and green without white specks, mildy ribbed with flat stem-end and attractive, average fruit weight 80 g and bears about 10 fruits per plant, early maturing and is ready for first harvest in about 60 days from sowing. It has a predominant female flowering tendency, field resistance to downy mildew and red pumpkin beetle. It is high yielding and gives about 200–250 q/ha.

Patty Pan: An introduction from USA and recommended by IIHR for cultivation during 1972. A bushy-type and fruits are disc-shaped, chalky white, tender and very attractive at edible stage. A short-duration variety (80–90 days). Yield 540 q/ha.

Early Yellow Prolific: Developed at IARI, Katrain. An early bush-type variety. Fruits are medium sized, warted and tapering towards stem end. Light yellow skin turns to orange-yellow on maturity. Flesh is tender at the stage it is consumed as vegetable.

Australian Green: An introduction at IARI, Katrain. Very early bush-type variety. Green fruits are dark-green with longitudinal white stripes all over, 25–30 cm long, 15–20 fruits/plant and very tender at edible stage. Yield 150–160 q/ha.

Pusa Alankar: This is an F1 hybrid developed by IARI, Katrain. It is early maturing, having uniform dark green fruits with light coloured stripes, slightly tapering towards the stem. The flesh is tender, delicious and fruits mature in 45–50 days. Yield 200–300 q/ha.

Cultural requirements

Sowing time: Summer squash is grown both in summer and rainy seasons. In the plains, summer-season crop is grown from January to March, whereas rainy-season crop is sown in June-July.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 3.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 1.0 m and between the hills is 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (50 kg N, 100 kg P, 50 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds/hill and cover them with soil and give a light irrigation. Generally soaking of seeds in water or carbendazim 50 WP (0.1%) solution for a few hours before sowing enhances germination. Seed rate/ha is 5–6 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (50 kg/ha), 40 days after sowing.

Pest and disease management

Follow the spray schedule as given for watermelon

Harvesting and yield

The fruits are picked before the seeds and skin of fruit harden, and used as vegetable. Generally the fruits are ready for picking in about 45 days after sowing and are picked tender within a few days after pollination. A fruit yield of 400–500 q/ha can be obtained.

Seed production

Cultural practices followed for the seed production crop are similar to that for vegetable production. Seed production is also similar to pumpkin. A seed yield of 150–200 kg/ha can be obtained.

ASH-GOURD

Ash gourd is a native of Malaysia from where it spread to Japan, Central America and West Indies. It was introduced to India from Japan. Originally cultivated in South-east Asia, the ash gourd is now widely grown in East Asia and South Asia as well. Ash gourd is also called as wax gourd, white pumpkin, white gourd, winter gourd, winter melon. In Hindi it is known as *petha* and *safed kaddu*. It is a

vine grown for its very large fruit, eaten as a vegetable when mature.

It requires very warm weather to grow but can be stored for many months much like winter squash. It is commonly eaten throughout winter in countries of deciduous vegetation such as China, as one of the few vegetables available during winter, hence its Chinese name literally means 'winter melon'. The winter melon can typically be stored for 12 months. Ash gourd is a popular vegetable cultivated throughout India. The fruits are cultivated mainly for culinary purpose. The fruits are covered by white, chalky wax, which deters microorganisms and helps impart an extraordinary longevity to the gourd.

Ash gourd is used as vegetable in various culinary preparations and well matured fruits are largely used for preparation of very popular sweet dish of north India, petha. The fruit has got many medicinal values and is extensively used in Ayurveda. Leaves and seeds are also used.

Breeding

Botany*[Benincasa hispida* (Thunb) Cogn] belongs to the family Cucurbitaceae and the genus *Benincasa*. It is the only member of the genus *Benincasa*. The plant bears a hairy stem, long heart shaped leaves, yellow, unisexual flowers and oval hairy fruits. Raw melon is sweet and has a thick white flesh. It forms a waxy coating as it grows. The fruit is fuzzy when young. The immature fruit has thick white flesh that is sweet when eaten. By maturity, the fruit loses its hairs and develops a waxy coating, giving rise to the name wax gourd, and providing a long shelflife. The ash goud may grow as large as 80 cm in length.

Breeding

Pandey *et al.* (2002a) reported performance of F_1 hybrid in ash gourd**.** Seventeen inbreds of ash gourd were crossed to produce 20 F_1 hybrids. Among the evaluated hybrids it was observed that AGH-11 was the most promising hybrid on the basis of yield, average fruit weight and length of fruit.

Improved cultivars

CO 1: This is a selection from a local type and released at TNAU. Crop duration is 150 days. It yields 200–250 q/ha. The vine is moderately vigorous, trailing up to 4 m. The leaves are dark green. Fruits are globular, green, large oblong oval in shape, ashy coated, about 35 cm length and 22 cm in girth with a mean weight of about 6.8 kg. The flesh is white and thick with less seeds. The first harvest can be done in about 100 days and it extends upto 140–150 days after sowing. Yield 250q/ha. Moderately resistant to pests and diseases.

CO 2: This is a selection from Coimbatore local and released by TNAU. The duration of the crop is 120 days. It is a small fruited variety, each fruit weighing 2–3 kg. It has good cooking quality. Vine is moderately vigorous and trails upto 200-250 cm. Leaves are medium dark green. Fruits are attractive, ashy coated, oblong or cylindrical in shape and are compressed on both sides. Fruits are of 25–30 cm long and 20–25 cm girth. The flesh is thick with white colour. It is suitable for both kitchen garden and commercial cultivation. Yield 340 q/ha.

Indu: High yielding variety with good flesh thickness released from the KAU.

Yield potential is 245 q/ha. Mean fruit weight is 4.82 kg.

Pusa Ujwal: This is released at IARI, New Delhi. Fruits ellipsoid, ideal for packing and long distance transportation. Average yield 450 q/ha. Maturity 120 days

Pusa Shakti: Developed by IARI, New Delhi. Fruits oblong-ellipsoid with greenish –white flesh. Average fruit weight 7.0 kg. Ideal for easy packaging and long distance transportation. Long storability, more than 6 months at room temperature. High TSS, vitamin C and minerals. Suitable for cooking as vegetable and also for preparing Petha sweet (candy). Maturity 140 days. Yield 250 q/ha.

Kashi Dhawal: Developed at IIVR, Varanasi. Fruits are of oblong shape. Duration 100–105 days after sowing. Most preferred variety for sweet preparation. Yield 550–600 q/ha.

Climate and soil

The optimal temperature for the growth of ash gourd is in the range of 24–27°C. The plants are adapted to a wide range of rainfall conditions. It tolerates a wide range of soil but prefers a well drained sandy loam soil that is rich in organic matter. The optimum soil *p*H is 6.0–6.7, but plants tolerate alkaline soils up to *p*H 8.0.

Cultural requirements

Sowing time: In rain fed areas it can be planted in June-July with the onset of monsoon, while as irrigated crop in plains it can be grown during October-December and February -April period.

Land preparation and sowing: Bring the soil to a fine tilth after 3–4 ploughings and harrowing. Broadcast 20–25 tonne/ha of FYM at the time of ploughing. Open up 3.0–3.5 m long and 30 cm wide sowing channels across the slope. Prepare 30 cm wide and 15 cm high ridges/bunds on either side of the sowing channel. Suitable spacing between two sowing channels is 3.0–3.5 m and between the hills is 1 m. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (50 kg N, 75 kg P, 50 kg K/ha) in the furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels 2 days before sowing.

Alternatively, pits of 45 cm × 45 cm × 45 cm size are dug at a distance of 1–2 m in a row and the spacing between rows should be 3.0–3.5 m. The pits are filled with mixture of top soil, FYM and NPK fertilizers. Then the seeds are sown.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds per hill and cover them with soil and give a light irrigation. The seeds germinate in about 4–5 days. Generally soaking of seeds in water or carbendazim 50 WP (0.1%) solution for a few hours before sowing enhances germination. Seed rate/ha is 5–6 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in

each hill or pit. Top dress the crop with nitrogen (25 kg/ha), 35–40 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. This facilitates intercultural operations and minimizes disease incidence and fruit rot. Generally vines are allowed to trail on the ground. Ash gourd is generally grown trailing on the ground by spreading dried twigs and coconut fronds on the ground.

Ash gourd is a cross-pollinated crop. Insects, especially bees, pollinate flowers. Pollination can be a problem during the wet season since bees are less active during overcast conditions. Introduction of bee hives ensures good pollination and avoids the need for hand-pollination.

Pest and disease management

Follow the schedule given for watermelon.

Harvesting and yield

Ash gourds are mature when the stems connecting the fruit to the vine begin to shrivel. Cut the fruits from the vines carefully, using pruning shears or a sharp knife leaving 3–4 inches of stem attached. Snapping the stems from the vines results in many broken or missing "handles." The fruits can be harvested at different stages depending on the purpose for which it will be used. Normally, green fruits are ready for harvest within 45–60 days; matured ones coated with powdery substance are harvested between 80 and 90 days after sowing. The fruit yield can vary depending on variety and crop management. Average marketable yields are 200–250 q/ha. The harvested fruits can be stored for several weeks in ambient conditions. It will keep for 2–3 months in temperatures from 10–12°C and 50–75% relative humidity. Avoid cutting and bruising the ash gourds when handling them.

Seed production

Cultural practices followed for the seed production crop are similar to that for vegetable production. Seed production is similar to pumpkin.

Harvesting should be done when the fruit stalk becomes dry and there will be a complete ashy coating on the fruits. Only healthy fruits of true to type and free from pest/disease infestation are to be selected for seed extraction. The selected fruits are cut into two halves by crosswise and length wise. Then remove the seeds along with pulp and crush with hand in excess quantity of water. Remove the floating fraction and collect the seeds settled at the bottom. Seed can also be extracted by acid method. Take the pulp along with seeds and hydrochloric acid (diluted 6 times with water) at 1:1 ratio and allow it for 30 minutes with stirring. Because of this seeds will settle down. Then the floating fraction is removed. And then collect the seeds settled at the bottom and wash it with water for three or four times. It is easy to dry the seeds extracted by acid method and also remove the fungal growth over the seed coat, thus seeds posses golden yellow colour and high vigour. The seed extraction by fermentation method posses poor vigour and off colour due to fungal activity.

The extracted seeds should be spread on gunny bags in a thin layer and dried under shade for 8–10 hours for one or two days. Then, seeds can be dried under

direct sunlight between 8–12 noon and 3- 5 pm. Avoid drying in between 12 noon to 3 pm, since the rays emitted from sun and the heat may affect the seed viability. While drying care must be taken to avoid clogging. After proper drying, white and dull yellow ill filled seeds are to be picked out manually and discarded. A seed yield of 300–350 kg/ha can be obtained.

SNAKE-GOURD

Snake gourd is a common cucurbitaceous vegetable native to India. It is most popular in the cuisine of South Asia and South-east Asia. Snake gourd is also known as serpent gourd, *chichinda*, and *padwal*. It is cultivated in India for its edible fruits. Young fruits are cooked. It can be used in curries or eaten as a vegetable like green beans. Mature fruits can be up to 1.5 m long and 10 cm thick. The bright red pulp around the mature seeds is extracted and used in cooking the same way that tomatoes are used. The shoots, tendrils, and leaves are also eaten as greens. Leaves and young shoots are cooked. It is a good source of carbohydrates, vitamin A, vitamin C and minerals.

Botany

Snake Gourd (*Trichosanthes cucumerina anguina* - (L.)Haines.; syn. *Trichosanthes anguina* - L.) belongs to the family Cucurbitaceae and the genus *Trichosanthes.* It is an annual climber growing to 5 m at a fast rate. It is frost tender. It is in flower from July to September, and the seeds ripen from September to October. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by Insects. *Trichosanthes cucumerina* is a tropical or subtropical vine, raised for its strikingly long fruit, used as a vegetable, medicine. Formerly, the cultivated form was considered a distinct species, but it is now regarded as a variety of the wild ancestor, as they freely interbreed:

1. *Trichosanthes cucumerina* var. *anguina* (L.) Haines – cultivated variant
2. *Trichosanthes cucumerina* var. *cucumerina* – wild variant

The narrow, soft skinned fruit can reach 150 cm long. Its soft, bland, somewhat mucilaginous flesh is similar to that of the ridge gourd and bottle-gourd.

Improved cultivars

Co-1: Developed at TNAU, Coimbatore. 160–180 cm long fruits with white stripes on dark green skin, flesh greenish. Each vine gives 10–12 fruits, average weight 500–750 g. Maturity 135 days. Yield 180 q/ha.

Co-2: Developed at TNAU, Coimbatore. 30–35 cm long, stout fruits, greenish, stripe less skin, ashy bloom. Vine length short, can accommodate more number of plants/ha at closer planting distances. The fruit is light greenish white and each fruit weighs 400–600 g. Maturity 125–130 days. Yield 250–300 q/ha.

MDU-1: Developed at TNAU, Coimbatore. A hybrid. Fruits have green skin with white stripes and are of medium length (around 60 cm). Maturity 125 days. Yield 200 q/ha.

APAU Swetha: Developed by APAU, Hyderabad. Long fruits, white skin with green stripes. Maturity 125–130 days. Yield 280–300 q/ha.

PLR (SG) 1: It is a pure line selection from white long type released by TNAU. This variety is suitable for cultivation under irrigated conditions only. Excellent cooking quality due to less fibre and high flesh content and does not twist due to maturity. This is having a yield potential of 350–400 q/ha. This variety can be cultivated during June–September, November–March and April–May. It thrives best in well drained, organic matter rich, sandy loam soils.

Kaumudi: This snake gourd variety that combines high yielding potential with superior quality is released by KAU, Kerala. It bears medium-sized, bright white fruits, and it is grown in almost all parts of the State including the hilly tracts. It has a potential to yield an average 620 q/ha. The white fruits grow to about 1 m in length, and each fruit will weigh on an average 1.3 kg. This variety is suitable for growing in both summer and rainy seasons. The duration of the crop is five months, with a prebearing period of 75 days. The fruits can be harvested in about 20 to 25 days after fruit set, when the flesh is still firm and tender. The fruits are tasty and are of high quality.

CO-4, TA-19, Baby, are the popular varieties of snake gourd.

Climate and soil

Snake gourd prefers a topical warm humid climate. Crop of rainy season is more successful than the summer crop. Plants grow best with short day lengths and stable temperatures above 25°C. Plants climb by means of tendrils and also have a slightly twining stem. It cannot tolerate frost. Snake-gourd requires a long growing season and takes 80–120 days. A loamy soil having *p*H range of 6.0–7.0 is best suited for the crop. It thrives well in a wide variety of soils ranging from sandy to moderately heavy provided the drainage system is quite efficient. Generally, they do not grow well in highly acidic or alkaline soil. Sandy loam soil gives a heavy early yield. It cannot grow in the shade. It requires moist soil.

Cultural requirements

Sowing time: It is grown both in summer and rainy seasons. In the plains, summer-season crop is grown from January- March, whereas rainy-season crop is sown from June-July.

Land preparation and sowing: Prepare the land by ploughing 2–3 times and bring it to a fine tilth. The spacing recommended is 2.0 m × 2.0 m. Pits of 45 cm × 45 cm × 45 cm size are opened. The pits are filled with top soil mixed with FYM and NPK fertilizers @ 12.5 tonne/ha FYM and 37.5 kg N, 50 kg P, 50 kg K/ha. Irrigate 2 days before sowing the seeds.

Seeds are sown @ 4–5/pit. About 3.0–4.0 kg of seeds are required for sowing one hectare. After sowing provide a light irrigation.

Intercultural operations

During the initial stages of growth, the crop has to be irrigated at an interval of 3–4 days. Later on depending upon the soil and weather, irrigation is to be given at in interval of 5–7 days.

Keep the field free of weeds till the vines cover the land completely. Weeding can be done manually by hand weeding. Sowing pits need to be hand weeded or

mulching can be done.

After two weeks, 2–3 healthy plants are retained and the others are removed. After a month of sowing the plants are top dressed with 37.5 kg N/ha and earthing up is done.

Generally, staking is required for snake gourd vines to get quality fruits. *Pandals* are erected for trailing snake gourd. Bamboo stakes and cross wires have to be provided for spreading the vines. The seedlings when start producing tendrils should be staked to thin bamboo poles using any natural or nylon thread so as to enable the vines to spread on the *pandal*. Five days after fruit set, at the tip of the developing fruits, a small stone is tied to prevent coiling or bending of growing fruits in long fruited varieties and however, short fruited types do not require such training.

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

The harvest starts from 78- 80 days after sowing and the crop lasts up to 135 days. The harvesting is done at an interval of 5–6 days. A total of 6–8 harvests can be done. On an average each vine gives 10–12 fruits (4–5 kg) and an yield of about 180- 250 q/ha can be obtained.

Seed production

As given for pumpkin.

POINTED-GOURD

Asom-Bengal region of India is considered as primary center of origin of pointed gourd. It is widely cultivated in the eastern part of India. It is found wild in the plains of north India from Punjab to Asom; it is also extensively cultivated all over the warmer regions of India, particularly in Uttar Pradesh, Bihar, West Bengal and Asom for its fruits. It is also known as the, *parwal, pravar, parval* in Hindi. Colloquially, in India, it is often called *green potato*.

Pointed-gourd is mainly used as a cooked vegetable with potato or other vegetables or even alone. It can also be used as pickles and sweets. Its young leaves are very nutritive and are used as leafy vegetable.

The fruits are used in making curry and fries. The leaves and tender shoots are used for preparation of syrup for convalescents. It is easily digestible and good for maintaining healthy heart and brain. It is used as ingredients of soup, stew, curry, sweet, or eaten fried and as meat stuffing.

It is a good source of carbohydrates, vitamin A, vitamin C and minerals. It also contains major nutrients and trace elements (magnesium, potassium, copper, sulfur and chlorine) which are needed in small quantities, for playing essential roles in human physiology. Root is a drastic purgative and useful in jaundice, anasarca and ascites.

Fruits contain 92.3% water, 2% protein, 0.3% fat, 0.5% mineral matter, 3% fibre and 1.9% carbohydrates, 0.03% Ca and 0.04% phosphorus.

Botany

Pointed Gourd (*Trichosanthes dioica* Roxb.) belongs to the family Cucurbitaceae and the genus *Trichosanthes*. It is a dioecious climber with perennial root stock; stems slender, angled, hispid. Tendrils usually forked. Leaves 7.5 cm × 5 cm, ovate-oblong or cordate, acute, sinuate-dentate, rough on both surfaces. Botanically, the crop is dioecious in nature and strictly entomophilous. Flowers are white; male peduncles paired, both one flowered; female solitary. The flowers open during early morning and close before sunset. Parthenocarpy has also been seen in parwal. Fruits 5–15 cm, oblong, globose, smooth, striped, orange red when ripe. Seeds are globose. There is no definite test to identify male and female plants at the young age on morphological traits except when it flowers.

Breeding

This is a highly cross pollinating and asexually propagated crop. There is no significant plant breeding work done in this crop. However, some high yielding clones have been developed by Narendra Deva University of Agriculture & Technology (NDUAT), Kumarganj, Faizabad; ICAR Research Complex for Eastern Region (ICAR-RCER), Patna, Bihar and Rajendra Agricultural University (RAU), Sabour.

Improved varieties/clones

FP-1: Developed at NDUAT, Faizabad. Fruits are round and green in colour. Yield 150–170 q/ha.

FP-3: Developed at NDUAT, Faizabad. Fruits are spindle shaped and green striped. Yield 125–150 q.ha.

FP-4: Developed at NDUAT, Faizabad. Fruits are spindle shaped and light green. Yield 150 q/ha.

Swarna Rekha: Developed at ICAR-RCER, Patna. Fruits are spindle shaped and green shaped. Yield 300–350 q/ha.

Swarna Alaukik: Developed at ICAR-RCER, Patna. Fruits are spindle shaped and light green. Yield 250–300 q/ha.

Rajendra Parwal-1: Developed at RAU, Sabour. Yield 140–150 q/ha.

Rajendra Parwal-2: Developed at RAU, Sabour. Yield 150–170 q/ha.

Arka Neelachal Kirti: This high-yielding variety of pointed gourd has been identified by IIHR for release.

Climate and soil

The pointed gourd thrives well under hot or moderately warm and humid climate. Frost or severe cold, especially below 5°C, are unfavourable for the crop. The crop can withstand water in places with abundant rainfall (Asom and West Bengal). During winter tilt crop remains dormant and vigorous growth starts only with the onset of spring.

High land with better drainage facility should be selected for pointed gourd cultivation. Sandy loam soil is ideally suitable for its cultivation. The soil should be rich in organic matter. Heavy soils as well as alkaline and saline soils are not suitable for its cultivation. Since it grows well under drought conditions, water

logging is quite detrimental for its growth. Hence, well drained fields should be selected.

Cultural requirements

Planting time: Early planting is done during February-April and late planting from May-July. In North Eastern States, it is grown as a summer crop. In Western U.P., Delhi, Haryana, Punjab, it can be grown as a rainy season crop. Planting is done during July-February in Southern region. The vines are to be trailed on bowers.

Planting material: Pointed gourd is vegetatively propagated through vine cuttings. Root suckers are also used for planting. The plants raised from seeds are weak with small leaves, taking about a year to fruit. Moreover the sex of the plants produced from seeds cannot be assured. Seed propagation is avoided due to poor germination (50% plants may be non-fruiting, i.e. male plants). In pointed gourd, the male and female flowers are borne on separate plants (dioecious). Both male and female plants, therefore should be planted to ensure proper fruit set. Cuttings are taken mostly from female plants. For proper fruit setting, there should be one male plant per 10–12 female plants. Usually cuttings from mature vines are taken in October, when fruiting is almost over, to ensure the sex and variety to be planted. The stem cuttings are made about 60–90 cm long from one year old fruiting vines of both male and female plants. In order to ensure maximum fruit set, 10–12% male plants is considered adequate. As it is a dioecious crop, for good fruit set normally 10% male plants should be accommodated.

Manure and fertilizers: 15–20 tonne/ha of FYM and a fertilizer dose of 80–100 kg N, 40–60 kg P and 60 kg K/ha has been recommended. Entire quantity of FYM, P and K should be applied as basal and N should be applied in two equal splits at 30th and 60th days after planting. Every year after pruning the same quantity of FYM and NPK fertilizers should be applied. Since immature fruits are harvested, nitrogenous fertilizer should be applied frequently.

Land preparation and planting: The land is thoroughly prepared by repeated ploughings and laddering. In the uplands, pointed gourd is also cultivated in pits. In this case 60–90 cm deep pits are dug at a distance of 2 m × 2 m (2,500–3,000 cuttings/ha). This distance may be reduced to 1.5 m × 1.5 m if the crop is to be trained on trellis or bowers (4,500–5,000 cuttings/ha). The pits are filled with sand, soil and farmyard manure in equal proportion. The following planting methods can be adopted:

1. ***Straight vine method:*** Long furrows of about 30 cm deep are prepared at a spacing of 1.5–2.0 m and the soil is mixed with farm yard manure. Irrigate the furrows 2 days before planting. The vine cuttings (60–90 cm length) are planted 15 cm deep in the furrows at a distance of 1 m by end to end method. After planting a light irrigation is given.
2. ***Ring method:*** Mounds are prepared at a spacing of 1.5 m × 1.5 m or 2.0 m × 2.0 m. Irrigate the furrows 2 days before planting. The vine cuttings (60–90 cm length) are coiled into a ring shape and planted directly on the mounds, covering 1/2 to 2/3 of ring under the soil. After planting a light irrigation is given. The portion of the vine cutting under the soil produces roots and

exposed portion produces new sprouts. Once it is taken as main crop, the vine cuttings that are planted in the field can produce fruits for 3–4 years. Fresh new plantings can be done when the yield starts declining.

3. ***Rooted cutting method:*** The cuttings from mature vines are planted during September-October in the nursery, where they are allowed to strike roots. The vine cutting (60–90 cm length) is made into a ring or coil. Insert the coil in polythene bag filled with a potting mixture in such a way that 2–3 nodes are outside the bag. Apply water with rose can sparingly and keep them under shade or polyhouse. Sprouting can be seen after 10 days of planting. Three month old rooted cuttings will be ready for planting in the main field during February-March. These can be planted as per the recommended spacing. This method can ensure cent per cent rooting.

At the time of planting we must ensure that number of male plants required for planting the area. Minimum of 10% male plants in the field are essential to ensure the availability of enough pollen grains required for fertilization and fruit setting. For every 15 female plants one male plant is a must to get highest fruit yield. Female plants nearer to male plant set more fruits than those away from it. The proportion of male to female plants must be checked at flowering time because it is easy to identify male flower (thin base) and female flower (swollen base). Excess male plants should be thinned out. It is cross pollinated by insects (Bharathi, 2007).

Intercultural operations

Hoeing and weeding should be done during the initial stage carefully. Once the vines start trailing on the ground, intercultural operations become difficult unless the plants are trained on bowers. Under such conditions, only pulling out of big weeds is possible. Irrigation becomes more important during summer when new shoots come up. Regular watering is necessary till the rain starts.

The green fruit yield in pointed gourd increases significantly when the vines are trained on trellis or bowers, since the interrow and intrarow space in reduced to 1.5 m × 1.5 m.

During winter the growth of meristematic tissue is retarded to a great extent. Therefore, the vines should be pruned 15 cm from the ground before the winter (October-November) sets in; also deep pruning should be done in October - November.

A technique for artificial-pollination in pointed gourd has been followed by an Odisha farmer. Male plants were planted in separate beds. Artificial pollination was done by plucking male flowers, removing petals, collecting pollens by hammering with a wooden stick in to a glass, diluted it with water, sieved it using a net and pollinated the female flowers by putting a drop of solution using a dropper. In rainy season, plucking of male flower buds was done in the afternoon, and they were kept overnight in water and plants were pollinated in the morning when the weather was favourable. Yield was 2.5 times higher when artificial pollination was practiced. Gross return obtained was ₹ 250,000/ha with an additional cost of ₹ 45,000 towards labour for artificial pollination (13 persons @ 1.5 hours per day per hectare was utilized for pollination). Fruit setting was better, size was good and weight of the fruit was more.

Harvesting and yield

Fruiting season will be from February to June. Second flush starts with the rains and fruiting continues till October. The fruits are ready for harvest 80–90 days after planting. Pointed gourds, like other gourds, are harvested at the immature stage while still tender with immature seeds. The fruits should be harvested twice a week. Delay in picking the fruits results in development of hard seeds. Harvesting of the fruits is done at mature green marketable stage, i.e. at 15–18 days after fruit set. The seeds usually harden by the time the fruit reaches edible stage or when there is delay of buds before their opening to get parthenocarpic (seedless) fruits.

In the first year, relatively a low yield of about 75–90 q/ha can be obtained. In the subsequent years (up to 4 years) a yield of 150–300 q/ha can be obtained. Yield declines 4^{th} year onwards. Under ordinary conditions, the pointed gourd fruits can be easily kept at room temperature for 3- 4 days.

Since pointed gourd is propagated by stem cuttings, seed production is not important.

BOTTLE-GOURD

Fig. 8. Bottle gourd

Bottle-gourd is reported to have originated in the African continent where the greatest diversity of gourd forms are found. However, ancient remains of gourds have been found in South America as well, and varied explanations exist as to how the species was spread to that region. The origin of bottle gourd is still undecided; it is found throughout the tropics and subtropics of both the hemispheres. Bottle-gourd is also known as whilc flower gourd or calabash gourd. In Hindi it is known as *lauki, ghia, dudhi, kaddu.*

The gourd has a storied history of use in both practical as well as decorative purposes. Until the advent of indoor plumbing, most drinking wells in the United States were equipped with a long-handled dipper gourd. Gourds were used in ancient times as containers in which to bury food, as masks, as protection from the sun, and as bowls, pipes and musical instruments. Present day use of the gourd has expanded to birdhouses.

In India the area under bottle-gourd is 105,000 ha with a production of 1984,000 t and productivity of 18.9 tonne/ha (NHB, 2012). Fruits of bottle gourd are cooked as vegetable. These are good sources of carbohydrates, vitamin A and C, and minerals. It contains 3.2% carbohydrates with 80–90% of water and small quantities of other nutrients.

Botany

Bottle gourd [*Lagenaria siceraaria* (Mol.) Slandl.] belongs to the family Cucurbitaceae and the genus *Lagenaria.* Plants that have white flowers (*e.g.*,

bottle gourd- Lagenaria siceraria). The bottle gourd is a vigorous, annual, running or climbing vine with large leaves and a lush appearance. It grows fast and may begin to flower only 2 months after seeding. The vine is branched and climbs by means of tendrils along the stem. The foliage is covered with soft hairs and has a foul musky odor when crushed. The leaves of the bottle gourd are up to 15 inches wide, circular in overall shape, with smooth margins, a few broad lobes, or with undulate margins. Leaves have a velvety texture because of the fine hairs, especially on the under-surface. Flowers are mostly monoecious. Flowers are borne singly on the axils of the leaves, the males on long peduncles and the females on short peduncles. The flowers are white and attractive, up to 4 inches in diameter, with spreading petals. The ovary is inferior and in the shape of the fruit. Otherwise, the male and female flowers are similar in appearance. The anthers are borne on short filaments grouped at the center of the flower. The stigmas are short, thickened, and branched. Bottle gourd blooms only at night and are pollinated by moths. Fruit size varies from medium small to very large. The mostly thin shelled fruit can be dried to form a mostly empty shell. The brownish seeds are numerous in a whitish green pulp. Each seed is somewhat rectangular in shape with grooved notches near the attached end.

Improved cultivars

Pusa Summer Prolific Long: Developed at IARI, New Delhi. Fruits long, club shaped, curved thin 'neck', 40 - 45 cm long, 20 - 25 cm thick at edible stage, green in color. Average fruit weight 1.3 kg. Suitable for sowing both in summer (February-March) and *kharif* (June-July). Maturity 60 days. Yield 250 q/ha in summer and 275 q/ha in *kharif.*

Pusa Naveen: Developed at IARI, New Delhi. Fruits are short, cylindrical, and straight without curve or 'neck', green color, 25–30 cm long, 15–20 cm thick. Average fruit weight 800 g. Suitable for sowing both in summer (February-March) and *kharif* (June-July). Maturity 55 days. Yield 275 q/ha in summer and 300 q/ha in *kharif.*

Pusa Sandesh: Developed at IARI, New Delhi. Fruits are round globular, medium size, green colour. Average fruit weight 500 g. Suitable for sowing in both summer (February–March) and *kharif* (June-July). Maturity 55 days. Yield 270 q/ha in summer and 300 q/ha in *kharif.*

Pusa Samridhi: This is released at IARI, New Delhi. Fruits long without neck. Average yield 272 q/ha in spring-summer and 308 q/ha in *kharif.* Superior in nutritional qualities. Maturity 50–55 days.

Pusa Santushti: Pear-shaped fruits. Average yield 260 q/ha in spring-summer and 290 q/ha in *kharif.* Sets fruits under low temperature (10–12°C) as well as high temp. (35–40°C). Maturity 55–60 days.

Azad Nutan: This variety can be cultivated in spring, summer and rainy seasons. It is early in fruiting, provides shining, light green and soft pubescent fruits. The fruits are almost neck free, soft and smooth. The fruits on an average weigh 1.0–1.5 kg each. They are ideal for distant markets.

Pant Lauki-4: This is a medium duration and high yielding variety, released by GBPUAT, Pantnagar. It has long hairy fruits and is 40 cm in length. The variety

bears heavily and is suitable for plain and hilly areas of north India. The yield potential of the variety is 350 q/ha.

Thar Samridhi: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. High yield potential having an average yield of 240–300q/ha. Yield per plant ranges from 4- 6 kg. Fruits having weight 450–700 g are ready to harvest at 50–55 days after sowing.

Pusa Meghdoot (F1): Developed at IARI, New Delhi. An hybrid from the cross between 'Pusa S.P Long' and 'S1 2'. Fruit is long, light green. Yield 258 q/ ha.

Pusa Manjari (F1): Developed at IARI, New Delhi. An hybrid from the cross between 'Pusa S.P. Round' and 'S1 11'. Fruits round, light green. Yield 253 q/ha.

Pusa Hybrid -3 (F1): Developed at IARI, New Delhi. Fruits long, slightly club shaped, straight without 'neck', green colour, 35–40 cm long and 15–30 cm thick. Average fruit weight 1.2 kg. Maturity 55 days. Yield 425 q/ha in summer and 470 q/ha in *kharif.*

Climate and soil

Slightly wet to semidry ecological conditions are suitable for this crop. Night and day temperature of 18–22°C and 30–35°C respectively is optimum for its proper growth and high fruit set. Select deep, well-drained soil with sandy or sandy loam texture. The *p*H of the soil should be between 5.5 and 6.5.

Cultural requirements

Sowing time: January-March and September- October are the ideal seasons. For the rainfed crop, sowing can be started after the receipt of first few showers during May-June.

Land preparation and sowing: Bring the soil to a fine tilth with 2–3 ploughings and harrowings. Broadcast 20–25 tonne/ha of farm yard manure after the first ploughing. Open up 30 cm wide sowing channels of 2.5–3.0 m length across the slope. Prepare 30 cm wide and 15 cm high ridges (bunds) on either side of the sowing channel. Keep 3.0 m spacing between two sowing channels. The spacing between the hills should be 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing charmels at the bottom of the ridges with the help of a pickaxe. Apply the fertilizer mixture (75 kg N, 100 kg P and 75 kg K/ha) in the shallow furrows made in the sowing charmels and cover it with soil. Irrigate the sowing channels two days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel at a spacing of 90 cm, 8–10 cm above the place where fertilizer has been applied. Sow 4–5 seeds per hill and cover them with soil and give a light irrigation. Seed rate per hectare is 3–4 kg.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in

each hill. Topdress the crop with nitrogen (25 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. Pandals can also be erected when the plants start vining.This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow spray schedule as given for watermelon.

Harvesting and yield

Harvesting in bottle gourd is done at short intervals when the fruits are tender. Bottle gourd may be harvested 55–75 days after sowing. The fruits should be harvested within 3 days of the shedding of the small hairs present on the skin. At this stage the seeds inside the pulp are as soft as pulp of the fruit and rind of the fruit is very tender. The open pollinated varieties yield 250–300 q/ha, while the yield of hybrids is generally more than 400 q/ha.

Seed production

Cultural practices followed for the seed production crop of bottle-gourd are similar to that for vegetable production. However, the following aspects are to be considered:

Isolation: To maintain genetic purity of the seed, the recommended isolation distance between seed crops of different cultivars of bottle gourd is 800–1000 m for foundation seed and 400–500 m for certified seed. Crops for basic seed production should be isolated by at least 1500 m.

Roguing: Roguing is done at 4 stages in bottle gourd as follows::

1. **Early vegetative stage:** The plants whose vegetative characters, foliage and vigour and resistance to specific pathogens are not in accordance with the cultivar description, should be removed.
2. **Before first flower open:** Plants having under developed fruit or female flower buds, whose characters are not true to type, should be removed.
3. **First fruit setting:** Developing fruits of such a plant which are not typical of the cultivar should be removed along with the whole plant itself.
4. **Ripe fruit:** Off-types are rogued out considering the colour, shape, etc., of mature fruits in accordance with cultivar description.

Pollination: As with most cucurbits, bottle gourd is monoecious, producing separate male and female flowers on the same plant. As a result they must have some pollinating agent present. Flowers generally only remain open for one day. Incomplete pollination produces poorly developed fruit that is often unmarketable, and reduces fruit set and thus yield. Flowers of bottle gourds open in late afternoon and evening and require pollination by nocturnal insects. They can also be hand pollinated by using a small paint brush to transfer pollen from the male to female flowers.

Fruit harvest for seed and seed extraction: Any deformed or malformed fruits should be removed earlier. The rest of the fruits are allowed in the plant to ripen

fully to dry. When fruits become dry and seeds rattle inside the shell, the fruits are harvested for seed extraction. Allow gourds to thoroughly dry on the vines before harvesting for seeds. Usually seeds are extracted by breaking open the dry and mature fruits. Seeds are washed in clean running water and dried up to 7% moisture level. Properly dried and stored, gourd seeds will last for several years.

The seed yield may be 500–600 kg/ha depending upon cultivar, successful pollination and management practices.

BITTER-GOURD

Fig. 9. Bitter gourd

Bitter-gourd is native to Africa but has been used in Chinese folk medicine for centuries as a 'bitter, cold' herb. It is a tropical vegetable, which is cultivated mainly in the Asian and African countries, It is also known as bitter melon and *karela.* Some *Momordica* species are grown in cultivation for their fleshy fruits, which are oblong to cylindrical in shape, orange to red in colour, prickly or warted externally.

In India the area under bitter gourd is 77,000 ha with a production of 866,000 tonne and productivity of 11.3 tonne/ha (NHB, 2012). Bitter gourd is a popular vegetable in some Asian countries, where the health benefits of the plant are well-known, particularly, its ability to lower blood glucose in diabetics. Bitter gourd has been used to treat diabetes in traditional medicine and is now commercially available as tea (from fruits or leaves), juice, extracts, and pills. Although, these products promise health benefits, most of the manufacturers do not offer scientifically proven data on the effectiveness of bitter gourd or their products. However, in recent years researchers worldwide have started to focus on the antidiabetic effects of bitter-gourd.

Botany

Genus *Momordica* is annual or perennial, monoecious or dioecious, climbers or trailers. Tendrils simple or bifid. Leaves simple, palmately lobed. Flowers small or large, yellow or rarely white. Peduncle mostly with large foliaceous bracts. Male flowers solitary, corymbose, racemose or umbellate; female flowers solitary. Calyx tube closed at bottom by 2–3 incurved oblong scales, lobes ovate lanceolate, entire. Corolla rotate or broadly campanulate, deeply 5 partite, lobes not fimbrate, obovate or oblong or petals free. Stamens 3, rarely 2, inserted at the mouth of the calyx tube, one 1-thecous, others 2-thecous, filaments short, free, anthers coherant at first, ultimately free, pistillode absent or glandular. Female perianths as in male. Staminode absent or glandular. Ovary oblong or fusiform, rostrate, minutely apiculate-excrescent. Ovules many, usually horizontal. Fruit oblong-fusiform, cylindric, baccate, tuberculate or muriculate, indehiscent or dehiscent by 3-valves

or irregularly exposing the seeds enveloped in scarlet pulp. Seeds turgid or flattened, smooth or sculptured, grooved at the margins. There are 3 important species, viz., *Momordica charantia, Momordica cochinchinensis, Momordica dioica,* which are used as vegetables.

Bitter-gourd (*Momordica charantia*) belongs to the family Cucurbitaceae and the genus *Momordica.* It is a gourd like fruit that grows in tropical areas, including parts of the Amazon, East Africa, Asia and the Caribbean. It is a climbing annual vine with long-stalked leaves, monoecious, yellow flowers and fruit that looks like a warty gourd, usually oblong and resembling a small cucumber. The young fruit is emerald green, turning to orange-yellow when ripe. At maturity, the fruit splits into three irregular valves that curl backwards and release numerous reddish-brown or white seeds encased in scarlet arils. All parts of the plant, including the fruit, taste very bitter, and all parts have been used medicinally in one culture or another.

Climate and soil

A long period of warm, dry-weather with 30–35°C temperature is optimum. The minimum temperature should not be below 18°C. Select deep, well drained soil with sandy or sandy loam texture. The *p*H of the soil should be between 5.5 and 6.5.

Improved cultivars

Pusa do Mausami: Developed by IARI, New Delhi. Fruits medium long (15–18 cm), green club shaped, unbroken ridges on the surface. Average fruit weight 80–100 g. Suitable for sowing in February-March for summer crop and June-July for *kharif* crop. Maturity 55–60 days. Yield 100–110 q/ha.

Pusa Vishesh: Developed at IARI, New Delhi. Fruits are medium long, medium thick, glossy green, smooth broken ridges on the surface. Average fruit weight is 100–150 g. Suitable for sowing only in February –March for summer season crop. Maturity 60 days. Yield is 125–130 q/ha. Suitable for pickle and dehydration.

Arka Harit: Developed at IIHR, Bengaluru. Fruits short to medium long thick, greyish green, smooth broken ridges on the surface. Average fruit weight 60–70 g. Suitable for growing in summer season. Maturity 60–75 days. Yield 75–90 q/ha.

Coimbatore Long: Developed at TNAU, Coimbatore. Fruits white, medium, long, thin, broken ridges on the surface. Average fruit weight 60–75 g. Suitable for growing in *kharif* season. Maturity 60–65 days. Yield 70–75 q/ha. Released by TNAU, Coimbatore.

VK-1 Priya: Developed at KAU, Trichur. Fruits are white and 35–40 cm long, heavy bearing. First picking at 60 days and yield 50 fruits/plant.

Pride of Gujarat: Fruits are small, roundish, whitish green in colour, weight 8–10 g/fruit.

Pant Karela-1: Highly-resistant to red pumpkin beetle. Developed by GBPUAT, Pantnagar.

Pant Karela-3: This is an early duration and high yielding variety, released by

GBPUAT, Pantnagar. The fruit is cylindrical and around 24 cm in length. The yield potential of this variety is 150–160 q/ha.

Pusa Hybrid-1: Developed at IARI, New Delhi. Fruits medium long, small to medium thick, glossy green. Smooth broken ridges on the surface. Average fruit weight 100 g. Suitable for growing in both summer and *kharif* seasons. Maturity 55–60 days. Yield 150–170 q/ha.

Pusa Hybrid-2: This is released by IARI, New Delhi. Fruits dark green medium long and medium thick, suitable for vegetable pickle, dehydration and export. Average yield is 180 q/ha. Maturity 52 days

The other varieties are Kalyanpur Baramasi, Preethi, Priyanka, SBG-101, SBG-2101 Shreyas.

Cultural requirements

Sowing time: The seed is sown from January-March for summer season crop, June-July for rainy season crop in the plains and March-June in the hills.

Land preparation and sowing: Bring the soil to a fine tilth after 2–3 ploughings and harrowings. Broadcast 25 tonne/ha of farm yard manure after the fIrst ploughing. Open up 30 cm wide sowing channels of 2.5–3.0 m length across the slope. Prepare 30 cm wide and 15 cm high ridges (bunds) on either side of the sowing channel. The ideal spacing between two sowing channels is 2.0 m and between the hills is 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pickaxe. Apply the fertilizer mixture (75 kg N, 100 kg P and 70 kg K/ha) in the shallow furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

Prepare sowing hills on the inner side of the ridges of the sowing channel, 8–10 cm above the place where fertilizer has been applied. The seed is sown by dibbling method. 4–5 seeds are sown in a hill at 2.5–3.0 cm depth. The seeds are soaked in water over night before sowing for better germination. After sowing give a light irrigation. Seed rate is 5–6 kg/ha.

Intercultural operations

Irrigate the crop once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (25 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. *Pandals* can also be erected when the plants start vining.This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow spray schedule as given for watermelon.

Harvesting and yield

The fruits are ready for picking 60–70 days after sowing. Harvesting is done

when the fruits are still young and tender. Harvesting is done at 4–5 days intervals. In most cases, it takes 12–15 days after pollination to attain marketable stage. Picking should be done carefully so that the vine may not be damaged. The fruits should not be allowed to mature on the vines. The harvested fruits may be stored for 3 to 4 days in cool condition. An yield of 100–150 q/ha can be obtained.

Seed production

Cultural practices followed for the seed production of bitter gourd crop are similar to that for vegetable production. However, the following aspects are to be considered:

Isolation: To maintain genetic purity of the seed, the recommended isolation distance between seed crops of different cultivars of bitter gourd is 800–1000 m for foundation seed and 400–500 m for certified seed. Crops for basic seed production should be isolated by at least 1,500 m.

Roguing: Roguing is done at 4 stages in bitter gourd as follows:

1. **Before 1st flowers open:** At this stage roguing should be done considering growth habit, vigour and foliage typical of the cultivar.
2. **Early flowering:** Roguing is done on the basis of observable characters of under-developed fruit, especially colour of spines and whether any specific seed-borne diseases are present.
3. **Fruit setting:** Off-types are rogued out considering the following factors such as (a) satisfactory level of productivity, (b) fruit characters, including size, shape and colour.
4. **Ripe fruit:** Off-types are rogued out considering the colour of ripe fruits in accordance with cultivar description, e.g. fruits either green, yellow, white and orange.

Fruit harvest for seeds and seed extraction: Any malformed or deformed fruits should be removed earlier and only healthy fruits are selected for seeds. The fruits are allowed to ripen fully. Bitter-gourd fruits are harvested when they are ripe and fruit colour at this stage is yellow. Fruits are crushed in water and seed are washed, dried and stored. Drying is continued until seed moisture reaches to about 10%.

The average seed yield is about 250–300 kg/ha depending upon cultivar, extent of pollination and cultural management.

SPINY BITTER-GOURD

Spiny bitter gourd, commonly known as gac from the Vietnamese gac (pronounced as yak), is a Southeast Asian fruit found throughout the region from Southern China to North-eastern Australia. It occurs wild and cultivated from India to Japan and throughout Malaysia. It is also known as gac, baby jackfruit, teasel gourd, spiny bitter melon, spiny bitter cucumber, giant spine-gourd, *kakrol*, sweet gourd, or cochinchin-gourd. It has been traditionally used as both food and medicine in the regions in which it grows. It is widely distributed in Asom and Garo hills of Meghalaya. Its immature tender green fruits are cooked as vegetable. Young leaves, flowers and seeds are also edible. There are some very unique fruits and vegetables which are grown wild and only available

Fig. 8a. Spiny bitter-gourd

during monsoon in coastal southern Karnataka and Kerala. One such vegetable is teasel-gourd, a wild spiny bitter melon (*Momordica cochinchinensis*) which looks like miniature bitter melon but not nearly as bitter. The fruits are beautiful green in colour and have tiny spines all over them. They are called *Kantola* (in Hindi).

Because it has a relatively short harvest season (harvest normally starts about 8 months after planting, harvest only lasts for 2 months), making it less abundant than other foods, gac is typically served at ceremonial or festive occasions in Vietnam. This probably also accounts for why the fruit is not know better throughout the rest of the world, commercial businesses do not like to deal with fruits with a short season, and the fruit must be ripe when harvested, it cannot be picked green.

It is most commonly prepared as a dish called *xôi gac*, in which the aril and seeds of the fruit are cooked in glutinous rice, imparting both their color and flavor. More recently, the fruit has begun to be marketed outside of Asia in the form of juice dietary supplements because of its allegedly high phytonutrients content.

Immature fruits, young leaves and flowers are used as vegetable. The seeds contain an oil that is used as an illuminant. Its roots froth in water and can be used as soap. The seeds have medicinal properties. Spiny bitter-gourd has been shown to be especially high in lycopene content. It contains up to 70 times the amount of lycopene found in tomatoes. It has also been found to contain up to 10 times the amount of β-carotene of carrots or sweet potatoes. Additionally, the carotenoids present in gac are bound to long-chain fatty acids, resulting in what is claimed to be a more bioavailable form. There has also been recent research that suggests that gac contains a protein that may inhibit the proliferation of cancer cells.

Botany

Spiny bitter gourd (*Momordica cochinchinensis*; synon: *M. mixta*, *Muricia cochinchinensis*) belonging to the family Curbitaceae and the genus *Momordica*. It is a relative of the common bitter-gourd (Momordica charantia) but its fruits are totally unlike the latter in terms of appearance and use. The spiny bitter-gourd is oval in shape and has short spines all over the rind of the fruit. In China the fruit is usually used only when it is ripe and that is when its rind turns into a bright orange colour. The size of the fruit of the spiny bitter-gourd seems to vary depending on the cultivar. Fruits are about 10 cm in length; can be much larger. The length of the fruit measures about 35 cm. The seeds from the spiny bitter-gourd are used in traditional Chinese medicine (TCM) and referred to as 'Semen Momordicae'. The Chinese name of these seeds is called 'Mu Bie Zi' which directly translates into 'wooden tortise seeds'. The seeds are about 4 cm in diameter, look

like as they do resemble the shells of tortises.

The spiny bitter-gourd plant is a tropical perennial vine but unlike the common bitter-gourd, this plant is dioecious which means that male and female flowers are borne on separate plants. Hence, in order to have fruits, one has to grow several vines nearby to ensure successful pollination. The common bitter-gourd produces flowers of both sexes on a single plant and one can get to harvest fruits by just growing one vine.

The flowers of the spiny bitter-gourd vine are produced in an interesting way. During development, they are all encapsulated inside a green bag like bract which eventually splits open in half to reveal the flower bud. Flowers produced by the plant are five petalled and are yellow in colour with a black eye in the middle. These flowers are frequently visited by bees which are attracted by the yellow colour of the flowers. The plant starts flowering around March to April until about August to September. The male flowers are smaller in size compared with the female flowers and the latter can be distinguished from the former like other Curcubit flowers via the presence of a baby fruit (ovary) located behind the petals. A young green coloured spiny bitter gourd fruit has numerous tubercles on the surface of the fruit. These will turn into rather stiff, hard spines when the fruit matures and the mature fruit becomes orange in colour. Fruit development occurs over a very long-time after pollination and the entire duration can take up to 4- 6 months.

It only fruits once a year, and is found seasonally in local markets. The fruit itself becomes a dark orange color upon ripening, and is typically round or oblong, maturing to a size of about 13 cm in length and 10 cm in diameter. Its exterior skin is covered in small spines while its dark red interior consists of clusters of fleshy pulp and seeds. Flowering starts about 2 months after planting and may continue for 6–8 months. In winter at high altitudes or during cool or dry seasons the plant remains dormant and start growing again from the tuberous root. It prefers warm humid conditions and in the wild it can often be found in open places on lowland riverbanks. It may yield 30–60 fruits per plant, each weighing 1–3 kg.

Cultivation

Greater cultivation of the under-utilised spiny bitter gourd fruit, by poorly resourced householders and farmers would potentially improve livelihoods, and, on a larger scale, meet the increasing demand for spiny bitter gourd as a health product. Cultivation methods need to be developed to suit small and large scale production and must consider the unpredictable ratio of male to female plants grown from seed and slow growth induced by cool temperatures.

In kakrol or sweet gourd, roots develop bigger tuber, leaves are bigger, flowers are large and white to light yellow in colour, there are three small circular dots at the base of petals which are deep blue in colour, anthesis occurs during early morning (3:30–6:30 AM) and flowers take 72 hours to open, fruits are large and oblong, individual fruit weight is around 60–80 g and can attain up to 500 g, fruit ripening starts from periphery to inner, fruits are light green to light yellow in colour, tough spines occur on fruit, it takes 26 days to reach edible maturity from days to bud formation, and flowering and fruiting are short period.

Arka Neelachal Gaurav is a high yielding variety of teasel gourd or spiny

bitter melon released by IIHR.

SPINE-GOURD

Spine gourd (*Momordica dioica* Roxb. ex Willd.) belongs to the family Cucurbitaceae and the genus *Momordica.* It is widely distributed in Asom and Garo hills of Meghalaya. Its immature tender green fruits are cooked as vegetable. Young leaves, flowers and seeds are also edible. This species is under cultivation in India for food purposes; the root is edible. The young, green fruits and tuberous roots of the female plant are eaten. In India this plant is cultivated for the fruit, which is the size of a pigeon's egg and knobbed. Average weight per fruit is 80 g. Spine gourd is also known as spiny gourd, *kantola,* bristly balsam pear, prickly carolaho, teasle gourd. In Hindi it is known as *ban karela* and in Sanskrit as *karkotaki.*

It is used as a vegetable in South Asia. It has commercial importance and is exported and used locally. The fruits are fried and sometimes eaten with meat or fish. Spine gourd is consumed by tribal groups living around the natural forest areas, especially at higher altitudes, where the native folks consume it as a daily vegetable. This vegetable did not gain much popularity until it was discovered to have a high nutritional and medicinal value. It is cooked the same way *karela* is cooked. 100 g edible fruit contains 84.1% moisture, 7.7 g carbohydrate, 3.1 g protein, 3.1 g fat, 3.0 g fibre and 1.1 g minerals. It also contains small quantities of essential vitamins like ascorbic acid, carotene, thiamin, riboflavin and niacin.

Cultivation

Spine gourd is cultivated in India. It is popular in some parts of India but hardly known in most places. This small, cute, spiny fruit is always used as a vegetable for cooking. It may look spiny but it is so soft to the touch that it won't hurt our fingers. It is green when unripe and will turn yellow when mature. The seeds are white and soft but it will turn dark brown and hard when ripe. As in most fruits used as vegetables, always get those still in the green stage.

This crop can be successfully cultivated in the plains and urban areas, as well as in countries where subtropical and tropical conditions prevail. This crop can provide additional nutrients and help the body develop natural immunity from many common ailments. Two genotypes, AAI/S-1 and AAI/S-4 have been found to be high yielding with an average yield of 600 g and 650 g/plant, respectively. It is planted during July-August.

In kartoli or spine gourd (*Momordica dioica*) roots develop small tuber, leaves are smaller, flowers small and yellow in colour, there is no circular dots existing on the base of petals, anthesis occurs during evening (4:30–6:00 PM) and flowers take 7–22 minutes to open, fruits are small and round to oval, individual fruit weight is around 10–15 g and can attain up to 30 g, fruit ripening starts from inner to periphery, fruits are dark green in colour, smooth and false spines occur on fruit, it takes 20 days to reach edible maturity from days to bud formation, and flowering and fruiting continue for longer period.

Arka Neelachal Shree, a high yielding variety of spine gourd has been developed by IIHR.

RIDGE-GOURD

Ridge gourd

Ridge gourd is a very popular vegetable for tropical and sub tropical parts of the country. India is considered as centre of the origin of Luffa. Ridge gourd also known as angled luffa, ridged luffa, vegetable gourd; In Hindi, it is known as *kali tori.* The tender, immature green fruits with prominent ridges are cooked as vegetable. These cucurbits are good sources of carbohydrates, vitamin A and C, and minerals.

Botany

The genus Luffa is well known because of the fibrous spongelike nature of its fruits and the wide cultivation of three species. Luffa comprises nine species, among them seven species are found in India. These are *L. cylindrica, L. acutangula, L. hermaphrodita, L. echinata, L. graveolens, L. tuberosa* and *L. umbellate* (Singh, 1991).

The genus *Luffa* includes tropical and subtropical vines classified in the Cucurbitaceae family. In everyday non-technical usage the name, also spelled loofah, usually refers to the fruit of the two species *Luffa acutangula* and *L. cylindrical* (syn: *Luffa aegyptiaca*). The fruit of these species is cultivated and eaten as a vegetable. The fruit must be harvested at a young stage of development to be edible. The vegetable is popular in China and Southeast Asia. When the fruit is fully ripened it is very fibrous. The fully developed fruit is the source of the loofah scrubbing sponge which is used in bathrooms and kitchens as a sponge tool. *Luffa* are not frost hardy, and require 150–200 warm-days to mature.

Ridge gourd [*Luffa acutangula* (L.) Roxb.] cultivars can be distinguishable on the basis of their fruit morphology. The uniform character of all the cultivars is ridged fruits. The fruits are no doubt angular in the beginning but as the fruits attain maturity, their angular nature slowly disappears and fruit becomes shorter in length. It has been observed that fruits of some cultivars become bitter in taste.

Sponge gourd (*L. cylindrical;* syn: *L. aegyptiaca*) is also known as smooth luffa, Egyptian luffa, dishrag gourd, gourd loofa. The fruits may be allowed to mature and used as a bath or kitchen sponge after being processed to remove everything but the network of xylem or fibres. Marketed as *luffa* or *loofah*, the sponge is used like a body scrub. In Karnataka's Malenadu (Western Ghats) it is known as *tuppadahirekayi*, which literally translates to buttersquash. It grows naturally in this region and is consumed when it is still tender and green, it is mostly used as a vegetable in curries, but is loved as a snack, bhajji, dipped in chickpea batter and deep fried. Once the fruit dries out, as the name goes it is used as a natural scrubber, washing sponge, Loofah. Usually two different type

are being grown by the farmers. One has dark green fruits and other has light green fruits. In the former, the seeds are grey, whereas in latter the seeds are ash coloured. The shape and size of the fruits are more or less similar.

The cultivated species of *L. hermaphrodita* is economically important, because its unripe fruits are used as vegitable. It bears bisexual flowers. The bisexual flowers have not been reported in any other Luffa species. *Luffa hermaphrodita* is cultivated throughout Bihar during the rainy season. However, cultivars vary in their fruit morphology (shape, size, number of fruits per inflorescence). The number of female flowers in an inflorescence varies from 4 to 15 and all the ovaries do not develop into fruits. Some cultivars of *L. hermaphrodita* bear seven fruits in each inflorescence and this appears to be a constant feature of the cultivars. On the basis of development of seven fruits per inflorescence, *L. hermaphrodita* is locally known as 'sathputia' meaning seven children (Ajmal Ali and Arun K. Pandey, 2006).

In *Luffa* species (vegetable sponges) the leaves are smooth and five lobed. Tendril is branched in sponge-gourd and ridge-gourd. Flowers are mostly monoecious. Plants have yellow to white flowers, and the large staminate flowers occur in clusters while the pistillate flower occurs as a single flower. Immature fruits are green, ridged and turn a straw color when mature. Seeds are flat, similar to watermelon seed, coloured black to blackish brown and are about 1.2 cm long. Tendrils are branched and vines are vigorous.

Climate and soil

Ridge gourd grows very well in a warm hot climate, the optimum temperature being 25°–30°C. Very high temperature especially in the early crop growth stage (more than 38°C) helps produce more male flowers, reducing the yield. Very low temperature also affects growth of vines. Sandy loam soil, rich in organic matter is most-suited for higher yield. Proper drainage is highly beneficial. The *p*H of the soil should be between 5.5 and 6.5.

Improved cultivars

Pusa Nasdar: Developed at IARI, New Delhi. Fruits are ridged, green, more suitable for summer season. Maturity 55–60 days. Yield 100–155 q/ha.

Arka Sujat: Developed at IIHR, Bengaluru. Lush green and tender medium long [35–45 cms] fruits with prominent ridges and delicate aroma, good transport and cooking qualities. Duration 100 days and yield 530 q/ha. Recommended for Karnataka.

Arka Sumeet: Developed at IIHR, Bengaluru. Lush green and tender long fruits [50–65 cm] with prominent ridges and delicate aroma, good transport and cooling qualities. Duration 110 days and yield 500 q/ha. Recommended for Karnataka.

Konkan Harita: It yield about 150–200 q/ha. Fruits are long (40 cm) uniform soft ridged and firm flesh. It is an early variety suitable for both the *kharif* and summer seasons. A fruit weights about 200 g. Released by BSKKV, Dapoli.

Phule Sucheta: It is developed by employing a pure line selection. Fruits are green, slender, tender, and medium in length (33.5 cm) with prominent ridges. It

shows filed tolerance to downy mildew. Suitable for in both the *kharif* and summer season of western Maharashtra. Average fruit weight is 118 g. A vine produces 18 fruits. Average yield is 119 q/ha.

CO 2: It is a selection from a germplasm type and released by TNAU. Each vine produces 8–10 fruits weighing 9- 10 kg. The fruits are green, very long (1 m) and fleshy. The crop duration is 120 days. It gives an yield of 250 q/ha.

Pusa Nutan: This ridge gourd variety developed at IARI is suitable both for spring-summer and *kharif* seasons. Its fruits are long (25–30 cm), straight, attractive green with 10 longitudinal angular ridges and a tapered neck, tender flesh, with an average fruit weight of 105 g. It gives first harvest in 45–50 days in *kharif* and 55–60 days in spring-summer. It gives an yield of 185q/ha. It has field tolerance to luffa yellow mosaic virus.

Swarna Manjari: This variety is released by ICAR-RCER, Ranchi. It is resistant to powdery mildew. It gives an yield of 180–200 q/ha.

Swarna Uphar: This variety is released by ICAR-RCER, Ranchi. It is resistant to powdery mildew. It gives an yield of 200–250 q/ha.

Cultural requirements

Sowing time: June–July is the sowing time for *kharif* crop, while February–March for summer crop.

Land preparation and sowing: Bring the soil to a fine tilth after 2–3 ploughings and harrowing. Broadcast 20–25 tonne of farm yard manure/ha after the first ploughing. Open up 30 cm wide sowing channels of 2.5–3 m length across the slope, prepare 30 cm wide and 15 cm high ridges (bunds) on either side of the sowing channel. Suitable spacing between two sowing channels is 3 m and between the hills is 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (75 kg N, 100 kg P and 35–70 kg K/ha) in the shallow furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

In south India, pits of 45 cm × 45 cm × 45 cm are dug and filled with farmyard manure and top soil. About 4–5 seeds are sown in each pit.

Prepare sowing hills on the inner sides of the ridges of the sowing channel, 8–10 cm above the place where fertilizer as been applied. Sow 4–5 seeds/hill and cover them with soil and give a light irrigation. Seed rate is 3–4 kg/ha.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (25 kg/ha), 30–35 days after sowing. When the plants start vining (35–40 days after sowing), vine guiding should be done. *Pandals* can also be erected when the plants start vining and the vines are allowed to grow. This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

Harvest the tender, immature green fruits with prominent ridges. First harvesting can be done at 55–65 days after sowing. Yield of 450–500 q/ha in 100 days, depending up on the varieties or hybrids grown can be obtained.

Seed production

Cultural practices followed for the seed production of ridge gourd crop are similar to that for vegetable production. Seed production is similar to bottle gourd. However, the following aspects are to be considered:

Ridge gourd is highly cross-pollinated. Different varieties should not be grown together as they contaminate by cross-pollination. Sponge gourd and ridge gourd should not be grown together in the same field for seed production, as they cross with each other.

Allow gourds to thoroughly dry on the vines before harvesting for seeds. Seed should be extracted from dried fruits. Ridge gourd fruits are fully dried and seeds come out after cutting the dried fruits. Seeds are cleaned by winnowing. Seeds are dried in sun for 2 days and subsequently 2–4 days under shade. A seed yield of 300–350 kg/ha can be obtained.

SPONGE-GOURD

Sponge-gourd

Sponge gourd is said to be native of India. Sponge gourd is also known as smooth gourd, smooth luffa, Egyptian luffa, dishrag gourd, dishcloth gourd, Chinese luffa, running okra, gourd luffa. It is known as *Ghiya tori, Nenua* in Hindi. Tender fruits are cooked as vegetable and are good sources of carbohydrates, vitamin A and C, and minerals.

Luffa cylindrica or Sponge luffa is a tropical running vine with rounded leaves and yellow flowers. The dried fruit fibres are used as abrasive sponges in skin care, to remove dead skin and to stimulate the circulation. The fruits are 30–50 cm long, cylindrical and smooth skinned. The interior of the gourds contains white flesh as well as a fibrous structure that is dried and used as a sponge. *Luffa cylindrica* is a very fast growing vine and will reach 3–4.5 m. The vines may be left to grow on the ground but grows best when given a support to grow on. If growing for sponges, allow the fruits to turn from green to yellow on the vine. Fruits will lose quite a bit of moisture and become light. Young fruit can be eaten raw like cucumber or cooked like squash, while the young leaves, shoots, flower buds, as well as the flowers can be eaten after being lightly steamed. The

seeds can be roasted as a snack.

Improved cultivars

Pusa Chikni: Developed at IARI, New Delhi. Fruits are smooth, dark green; suitable for rainy season; poor yielder. Maturity 50–55 days. Yield 110–120 q/ha.

Pusa Supriya: Developed at IARI, New Delhi. Short vine growth, fruits are light green in colour and smooth, tender; 12–14 fruits per vine. Suitable for growing in both spring-summer seasons. Maturity 40–45 days. Yield 100–120 q/ha.

Pusa Sneha: Developed at IARI, New Delhi. Fruits are dark green, 20–25 cm long, staright; tolerant to high temperature. Suitable for cultivatiom in spring – summer and rainy seasons. Maturity 45–50 days. Yield 110–130 q/ha.

Swarna Prabha: This variety is released by ICAR-RCER, Patna, Bihar. It is tolerant to powdery mildew and downy mildew diseases. It gives an yield of 250–300 q/ha.

Climate and soil

Sponge gourd can be grown from tropical to subtropical climates. Warm humid conditions favour its cultivation. Very low temperature is deleterious and frost kills its plants. Well drained loamy soils are ideally suited though it can be grown on a wide variety of soils.

Cultural requirements

Sowing time: June–July is the sowing time for *kharif* crop, while February–March for summer crop.

Land preparation and sowing: Bring the soil to a fine tilth after 2–3 ploughings and harrowing. Broadcast 20–25 tonne/ha of farm yard manure after the first ploughing. Open up 30 cm wide sowing channels of 2.5–3 m length across the slope, prepare 30 cm wide and 15 cm high ridges (bunds) on either side of the sowing channel. Suitable spacing between two sowing channels is 3 m and between the hills is 90 cm. Prepare the irrigation channels along the slope to irrigate the sowing channels. Make shallow furrows in the sowing channels at the bottom of the ridges with the help of a pick axe. Apply the fertilizer mixture (75 kg N, 100 kg P and 35–70 kg K/ha) in the shallow furrows made in the sowing channels and cover it with soil. Irrigate the sowing channels two days before sowing.

In south India, pits of 45cm × 45cm × 45cm are dug and filled with farmyard manure and top soil. About 4–5 seeds are sown in each pit.

Prepare sowing hills on the inner sides of the ridges of the sowing channel, 8–10 cm above the place where fertilizer as been applied. Sow 4–5 seeds per hill and cover them with soil and give a light irrigation. Seed rate is 3–4 kg/ha.

Intercultural operations

Irrigate once in 4–5 days depending upon the soil and weather conditions. Do the weeding and hoeing during the first 45 days of plant growth. Thinning of plants should be done 25–30 days after sowing, retaining 2 good seedlings in each hill. Top dress the crop with nitrogen (25 kg/ha), 30–35 days after sowing.

When the plants start vining (35–40 days after sowing), vine guiding should be done. *Pandals* can also be erected when the plants start vining and the vines are allowed to grow.This facilitates intercultural operations and minimizes disease incidence and fruit rot.

Pest and disease management

Follow the spray schedule as given for watermelon.

Harvesting and yield

Its fruits should be harvested at tender stage. If allowed to develop fully, they become spongy or fibrous which are unfit for vegetable purpose. On an average its yield is 150–200q/ha.

Seed production

Cultural practices followed for the seed production of sponge gourd crop are similar to that for vegetable production. Seed production is similar to bottle gourd. However, the following aspects are to be considered:

Sponge gourd is highly cross pollinated. Different varieties should not be grown together as they contaminate by cross pollination. Sponge gourd and ridge gourd should not be grown together in the same field for seed production, as they cross with each other.

Allow gourds to thoroughly dry on the vines before harvesting for seeds. Seed should be extracted from dried fruits. Sponge gourd fruits are fully dried and seeds come out after cutting the dried fruits. Seeds are cleaned by winnowing. Seeds are dried in sun for 2 days and subsequently 2–4 days under shade.

The growers in one particular village should grow only one variety of these cucurbits, quite adapted to that place and select fruits for seeds from the plants which were tagged in the beginning. This avoids any cross pollination because no other variety is growing in that area and best fruits are selected from a large population of the same strain thus maintaining the purity of the best variety adopted in the area (Nath *et al.* 2002).

IVY-GOURD

Ivy gourd is reported to be native to tropical Africa and Asia, probably India. Its native range extends from Africa to Asia, including India, the Philippines, China, Indonesia, Malaysia, Thailand, Vietnam, eastern Papua, New Guinea, and the Northern Territories, Australia. It is an under exploited perennial cucurbitaceous vegetable grown in eastern and southern parts of the country. Although this is considered as an underutilized vegetable, it is grown extensively in Chhattisgarh, West Bengal, Bihar and Karnataka on a commercial scale and giving remunerative returns to farmers. It can be maintained as a perennial crop by regular pruning. The ivy-gourd is also known as Indian gherkin, scarlet gourd, baby watermelon, little gourd, gentleman's toes, *tindora, kundru.*

A rampant vine with ivy shaped leaves that can completely smother other vegetation. Stems become thick and somewhat succulent with age and produce roots where they contact soil. White tubular star shaped flowers which are either male or

female. The immature fruit resembles a small dark green cucumber with paler stripes. These fleshy fruits (2.5–6 cm long and up to 3.5 cm wide) turn bright scarlet red as they mature and contain numerous tan coloured seeds (6–7 mm long).

The young leaves and slender tops of the stems are cooked and eaten as a potherb, in soups, or as a side dish, often with rice. The young and tender green fruits are eaten raw in salads, or boiled, steamed, fried, added to dishes like curry or soups or even fermented. The ripe, scarlet fruit is fleshy, on the sweet side and eaten raw. It can also be candied. The fruit is often available in speciality markets and is very common in India. In Hawaii it is known as "Thai spinach." It is best eaten when the gourd is still green. The roots and stems are succulent and help the ivy gourd plant store water through dry seasons. The ivy gourd's shoot tips are also commonly used in Asian cooking. A lot of people in India believe that it also regulates the blood sugar level in our body.

Ivy-gourd is rich in beta-carotene. Fruits contain a fabulous mix of complex carbohydrates, fibre and a vast array of B vitamins and minerals. It is quite a valuable source of nutrients. New research shows that consuming 50 g of kundru daily can help keep your blood sugar under check. Fruits contain 92.3% water, 2% protein, 0.3% fat, 0.5% mineral matter, 3% fibre and 1.9% carbohydrates, 0.03% Ca and 0.04% phosphorus. They are cooked as vegetable.

Presently vegetable growers are cultivating this vegetable in larger areas and exporting their produce to cosmopolitan cities and farmers are getting highly remunerative prices for their produce. Among vegetables it is considered as one of the major economically viable vegetable crops

Botany

Ivy gourd [*Coccinia grandis* (L) Voigt; syn. *C. cordifolia*, *C. indica*] belongs to the family Cucurbitaceae and the genus *Coccinia.* It is a tropical vine. Plants of this species are semiperennial creepers and dioecious, which means it requires two plants of opposite sexes to form the gourd's seeds. There is no definite test to identify male and female plants at the young age on morphological traits except when it flowers. Leaf lamina cordate, ovate and oblong, with basal lobes narrow, angular or lobed at base. The stem is a herbaceous climber or perennial slender climber with occasional adventitious roots forming where the stem runs along the ground. The tendrils are long, elastic with coil like springy character that can wrap around the host to the entire length. Tendril is simple, rarely bifid.

The ivy gourd's star shaped, white flowers turn into a small green fruit or gourd that later turns scarlet. Each fruit is filled with many seeds, which play a large part in the vine's spread. Fruit is a 'pepo' botanically. Fruits are small, round or thick long, green with white stripes or green with no stripes. The green fruit of ivy gourd resembles a small, smooth pointed cucumber or long little watermelon. It is packed with seeds inside and while the skin is not tough but has just a little more resistant than a cucumber. The fruit grows red from the inside out. It is possible to have it reddish on the inside and not yet red on the outside. When green it is ever so slightly sour. When fully ripe it gets very soft. The seeds do not go dormant. However, growing ivy gourd from seed is a lengthy process because it takes so long to mature. In some areas, the ivy gourd reproduces through cuttings

or pieces, or birds disperse its seeds.

Breeding

This is highly cross pollinating and asexually propagated crop. There is no significant plant breeding work carried out in this crop. However, studies have been made on pollen morphology and physiology in *Kundru*. High-yielding clones have been developed by KAU and IIHR. Allahabad Agricultural Institute-Deemed University, Allahabad, U P has also identified 6 high yielding genotypes, namely AAIIG 1, AAIIG 2, AAIIG 3, AAIIG 4, AAIIG 5 and AAIIG 6 (Bharathi, 2007; Anon., 2011c; Hitesh Nag *et al.* 2012).

Improved cultivars

Sulabha: This is an improved variety of ivy gourd with long fruits released by KAU, Vellanikkara. Fruits are 9.5 cm long and weigh about 18 g each at maturity. The fruit shape is cylindrical and fruit colour is pale green with continuous striations. This variety comes to flowering in 37 days after planting, and the first harvest can be taken in 45–50 days. It produces female flowers in the axils of leaves. The fruits are set parthenocarpically. It yields on an average 6 tonne/ha/year.

Arka Neelachal Kunkhi: This high yielding variety of ivy gourd has been identified by CHES, Bhuvaneshwar of lIHR, Bengaluru, for release.

Arka Neelachal Sabuja: This high yielding variety of ivy gourd has been identified by CHES, Bhuvaneshwar of lIHR, Bengaluru, for release.

DRC-1: This is a high yielding genotype identified by UAS, Dharwad. It gives a yield of 842 q/ha (29 kg/plant/year).

Climate and soil

Ivy gourd prefers a warm and humid climate. The plants remain dormant during winter season. They grow best in sandy loam soils and are not adapted to heavy soils. The plants require perfect drainage and are very susceptible to waterlogging.

Cultural requirements

Planting time: Ideal planting time is May-June and September-October.

Planting material: It is propagated through vegetative means by stem cuttings. 12–15 cm long stem cuttings of pencil thickness with 5–6 leaves are taken. The male and female flowers are borne on separate plants (dioecious). Both male and female plants, therefore should be planted to ensure proper fruit set. Cuttings are taken mostly from female plants. For proper fruit setting, there should be one male plant per 10–12 female plants. Usually cuttings from mature vines are taken in October, when fruiting is almost over, to ensure the sex and variety to be planted. The stem cuttings are made about 60–90 cm long from one year old fruiting vines of both male and female plants. In order to ensure maximum fruit set, 10–12% male plants is considered adequate. As it is a dioecious crop, for good fruit set normally 10% male plants should be accommodated.

Land preparation and planting: The land is prepared by ploughing and harrowing. Stem cuttings are planted in pits of 60 cm × 60 cm × 60 cm size dug at

a spacing of 2 m × 2 m. 10 tonne of well decomposed FYM is mixed with the soil up to a depth of 45 cm.

25 tonnes/ha of FYM and a fertilizer dose of 80 kg N, 50 kg P, 50 kg K/ha is recommended for ivy gourd. Full dose of P and K and half dose of N should be applied as basal dose. In addition, 10 kg FYM/basin should be applied along with basal dose of NPK fertilizers and fertilizers should be properly mixed in the basins of plants. The pits should be irrigated lightly 2 days before transplanting of cuttings.

About 2–3 stem cuttings are transplanted 3 cm deep in each pit. About 10% male cuttings are sufficient to pollinate female plants in 1 ha of land. About 7,500 stem cuttings are required for planting 1 ha area.

The remaining half dose of N (40 kg) can be applied at monthly intervals in 4 split doses from June or July. There should be sufficient moisture in the soil at the time of fertilizer application.

Every year after pruning the same quantity of FYM and NPK fertilizers should be applied. Since immature fruits are harvested, nitrogenous fertilizer should be applied frequently.

Intercultural operations

Hoeing and weeding should be done during the initial stage carefully. Once the vines start trailing on the ground, intercultural operations become difficult unless the plants are trained on bowers. Under such conditions, only pulling out of big weeds is possible. Irrigation becomes more important during summer when new shoots come up. Regular watering is necessary till the rain starts.

Young plants require support to keep their young shoots growing upright, since the new shoots are delicate. For commercial crop, plants are trained on a bower system. In the initial stages the plants are supported by stakes so that they grow straight to the bower system and spread their branches. Tendrils of this plant are long and elastic with coil like springy characters and they will coil on the G.I. wire of the bower system.

The green fruit yield in pointed gourd increases significantly when the vines are trained on trellis or bowers. During winter the growth of meristematic tissue is retarded to a great extent. Therefore, the vines should be pruned 15 cm from the ground before the winter (October -November) sets in; also deep pruning should be done in October -November.

As it is a dioecious crop, for good fruit set normally 10% male plants should be accommodated. The proportion of male to female plants must be checked at flowering time because it is easy to identify male flower (thin base) and female flower (swollen base). Excess male plants should be thinned out. It is observed that ivy gourd produces fruits by vegetative parthenocarpy in the absence of male plants. It is cross pollinated by insects (Bharathi, 2007).

Cultivation of the crop during rain is very challenging as the plant is highly intolerant to excess rainfall. Pollination does not occur as the pollen grains are washed away. Water logging at the base of the pits should be checked and as a preventive measure, the pits must be covered with soil so as to get a heap and all weeds around the heap must be removed.

The plants should be allowed to climb over *pandal* or trellises. The plants should be irrigated during hot weather and care should be taken to keep the root zone sufficiently moist.

The remaining half dose of N (40 kg) can be applied at monthly intervals in 4 split doses from June or July. There should be sufficient moisture in the soil at the time of fertilizer application.

When the vines start to look a bit weak and there is a change in colour of the leaves to yellow, pruning is to be done. Most important in cultivation of coccinia is the timing of pruning the vines. Repeated prunings are recommended as the newly developing vines produce more flowers and yield more. Pruning the vines must be done every 3- 4 months to maximize yield.

It is recommended to irrigate the crop at the time of plucking the fruit. Mornings and evenings when the sun is not harsh is a good time to irrigate the crop. Irrigating once in two days when soil temperature is high is recommended. There is no need of irrigation during rainy season however, heaping of the soil around the base of the stumps is done to prevent stagnation of water.

Pest and disease management

Follow spray schedule as given for watermelon.

Harvesting and yield

Ivy gourd bears fruits almost throughout the year where mild winter prevails. In regions where severe winter occurs, it bears fruits for 8–9 months.
Fruiting starts during March to June. Second flush starts with the rains and fruiting continues till October. The economic life of *kundru* is 3–4 years. Fruits of k*undru,* like other gourds, are harvested at the immature stage while still tender with immature seeds. The fruits should be harvested twice a week. Maximum yield of 10 kg/creeper has been recorded. On an average, it gives 110–150 q/ha of fruit yield.

Ivy gourd is propagated by stem cuttings. Hence seed production is not important.

CHOW-CHOW

Chow-chow is native to humid tropical regions of Central America and the Caribbean. It was introduced into the Antilles and South America between the 18^{th} and 19^{th} centuries. The first botanical description mentioning the name *Sechium* was in fact done in 1756 by P. Brown who referred to plants grown in Jamaica. During the same period, the chayote was introduced into Europe, from where it was taken to Africa, Asia and Australia, while its introduction into the United States dates from the late 19th century. Chayote has now spread throughout the tropics and sub-tropics. Today, chayote is grown commercially in the US, Central America, South America, the Caribbean, India, Nepal, Myanmar, North Africa, New Zealand, Australia, and China. *Sechium edule* is a species which was undoubtedly domesticated within the cultural areas of Mesoamerica, and specifically in the region lying between southern Mexico and Guatemala. Mesoamerica (Spanish: *Mesoamérica*) is a region and cultural area in the Americas,

extending approximately from central Mexico to Belize, Guatemala, El Salvador, Honduras, Nicaragua, and northern Costa Rica, within which a number of pre-Columbian societies flourished before the Spanish colonization of the Americas in the 15th and 16th centuries.

It is a popular vegetable in northeast hilly region commonly called squash and grows abundantly without much care and attention in high hills of Meghalaya, Manipur, Mizoram, Nagaland and Sikkim. It is cultivated on a large scale in the lower Palani hills of Madurai, Dindigul and the Nilgiris districts in Tamil Nadu at elevations of 850–1,700 m as a initial shade crop for coffee. It is also grown in certain parts of Karnataka. It is grown in Himachal Pradesh and its neighbouring states in the lower hills.

Chow-chow is also known as chayote, mirliton, christophine, choloes, chu chu, cho cho, vegetable pear, custard marrow, choko, pepinella, and sou sou. The name chayote comes from the Aztec 'chayotl', and was once a staple food of both the Aztecs and Mayans. In the West Indies, it is called 'christophine' after Columbus, who reputedly introduced it to the islands. Chayote (pronounced: chy-O-tay) is a vigorous, scrambling, tuberous rooted perennial climber which can spread to 15 m, producing huge tubers. It is a member of the gourd family, and grown for its starchy, edible fruit and seeds.

Technically, chow-chow is a fruit; but most often used as a vegetable. It looks like a large, green pear, but having a number of deep folds in the skin. Some varieties have smooth skins, while others have dots of prickly spines on the surface. The flesh is crisp and white, with a large white oval seed in the center. Its flavour is a bland mix of zucchini, green beans, and cucumber. The skin is also edible, but many prefer to peel it. When it is peeled, it will leave a slimy residue on the hands that is difficult to wash off. It is often used in place of potatoes at a meal, and is cooked like potato. The seed is edible and, when cooked, tastes like a cross between a lima bean and an almond. It is soft enough to be chopped up with the flesh and used along with it giving the entire dish a pleasant flavour. It can also be eaten raw in salads, and is an excellent addition to soups. It also keeps well in a cool, but humid place and can be frozen like a summer squash. Chow-chow is a good source of fibre, vitamins C and B6, folate, potassium, and magnesium (Grubben, 2004).

Unripe fruits are used as vegetable. Chow-chow is basically used for human consumption, not just in the America but in many other countries. In addition to the fruit, stems and tender leaves, the tuberous parts of the adventitious roots are also eaten. They are much appreciated as a vegetable and are either just boiled or used in stews and desserts. The fruits, tubers, seeds, and leaves have long been used by the native Americans. Chow-chow contains a large, nutty flavoured seed much prized by cooks. In the Caribbean, chow chow is used to tenderize meats. The seeds are even considered a delicacy.

Chow-chow is the richest among gourds, in nutritive value, particularly in carbohydrates (6.3%) and calorific value. Its calorific value and carbohydrate content is high, chiefly in the case of the young stems, root and seed, while the micronutrients and macronutrients supplied by the fruit are adequate. The fruit and particularly the seeds are rich in amino acids such as aspartic acid, glutamic

acid, alanine, arginine, cysteine, phenylalanine, glycine, histidine, isoleucine, leucine, methionine (only in the fruit), proline, serine, tyrosine, threonine and valine. The edible parts of chow-chow have a lower fibre, protein and vitamin content than other plants. The fruits, stems and young leaves as well as the tuberized portions of the roots are eaten as a vegetable, both alone and plain boiled, and as an ingredient of numerous stews. Because of its softness, the fruit has been used for children's food. The results have been positive and have enabled jams and other sweets to be prepared while also producing dried fruit which can be used as a vegetable after a certain time. Because of their flexibility and strength, the stems have been used in the craft manufacture of baskets and hats. In India, the fruit and roots are not only used as human food but also as fodder. Since it is a perennial, the best production is obtained 2–3 years after the plant is established.

Botany

Chow-chow (*Sechium edule* Jacq.) belongs to the family Cucurbitaceae and the genus *Sechium*. The genus was long considered to be monospecific, but currently, eight species, all distributed in Central America, are recognized. One species, *S.edule*, is widely cultivated (2n=24). It is a perennial, monoecious, climber with large tuberous roots. It is a perennial creeper with annual vine growth habit. The stem is longitudinally furrowed and thick at base. The leaves are broadly ovate. The vine bears large tendrils which act as support. Flowers are monoecious or unisexual. Male flowers are peduncled in clusters and female flowers are solitary, usually four in number produced on the axils of leaves. The flowers are light to cream yellow in colour. The fleshy fruit is light green or dark green, and has longitudinal furrows. The surface of the fruit is slightly prickly and wrinkled with 5–7 ridges. The flesh is white in colour. Fruit has deep slightly fissure at the blossom end, which is the site for seed germination. The seed is large, flat and white with 3–5 cm in length.

A distinctive botanical trait of the fruit is its ability to sprout from the seed embryo while the fruit is still attached to and growing on the vine, an undesirable and unique horticultural phenomenon defined as vivipary, i.e. the fruit is vivipary in nature. Undesirable sprouting may also occur after harvest, during transit, marketing, and in the kitchen counter. Almond sized chow chow seeds cannot be dried and saved for planting: It germinates only inside the fruit and will often do so while still on the vine— so the seed must be planted with its fleshy 'shell' intact.

It is a perennial rooted cucurbit, with climbing vines and leaves resembling those of the cucumber. Its vine can grow as high as 12–15 m. Its leaves are heart shape, 10–25 cm wide and with tendrils on the stem. The flowers are cream coloured or somewhat green that comes out beneath a leaf or branch. It is a monoecious plant but male and female flowers borne in separate places. If the vine is male, the flowers are in cluster; if female, the flowers are solitary. The light green, pear shaped fruit, with deep ridges lengthwise, may weigh as much as 1 kg, but most often is from 170–340 g. The chayote fruit differs from its multi-seeded relatives, in that it contains only a single, flat edible seed. Fruits may be slightly grooved, and its skin may be prickly or smooth.

Cultivars

There are two types of varieties in chow-chow, namely green fruited and white fruited. Improved varieties are lacking and local strains are popularly grown. round white, long white, pointed green, broad green and creamy green varieties are grown. In north east India, the fruits exhibit minor variations.

Climate and soil

The crop favours temperature range between 18–22°C and comes up well at higher attitudes of 1,200–1,500 m. In the plains, it grows under moderate temperature during winter season. It is highly sensitive to frost. A rich well drained loamy soil with sufficient moisture and high organic matter will be ideal to grow chow chow. Soil pH of 5.5–6.5 is ideal.

Cultural requirements

Planting time: Planting is done during April-May in hills and July-August in plains.

Planting material: Propagation is by planting the entire fruit. Young basal shoot cuttings are also sometimes used. The whole fruit is planted as a seed. Each fruit has a single large seed that sprouts as soon as the fruit reaches maturity unless placed in cool storage. Fruits stored at 10°C remain in good condition for planting for as much as 6–8 weeks, although shriveling and decay are common.

Seeds of chow chow are difficult to locate since the whole fruit is used as a seed. It is not marketed through retail seed catalogues, and is often available only in localities where the plant is grown. Planting material (whole fruits) are normally available locally from fellow gardeners or growers.

Land preparation and planting: The land should be prepared by ploughing and harrowing. Pits of 60 cm × 60 cm × 60 cm size are dug out about 3 m apart. Since the vine is large and vigorous, plant the seeds no closer than 3 m apart and provide a trellis or some means of support.

25 tonne/ha of FYM and a fertilizer dose of 80 kg N, 50 kg P, 50 kg K/ha is recommended for ivy gourd. Full dose of P and K and half dose of N should be applied as basal dose. In addition, 10 kg FYM/basin should be applied along with basal dose of NPK fertilizers and fertilizers should be properly mixed in the basins of plants. The pits should be irrigated lightly 2 days before transplanting of cuttings.

The remaining half dose of N (40 kg) can be applied at monthly intervals in 4 split doses from June or July. There should be sufficient moisture in the soil at the time of fertilizer application.

Every year after pruning the same quantity of FYM and NPK fertilizers should be applied. Since immature fruits are harvested, nitrogenous fertilizer should be applied frequently. An oversupply of nitrogen will result in excessive growth at the expense of fruit production.

Fully matured sprouted fruits collected from high yielding vines are planted in pits @1–2. The fruit should be completely covered with soil to protect the bud from damage. Deep planting will lead to fruit rot. Planting is done with the broad

end of the fruit or blossom end of the fruit pointing down at 45 degree angle on soil surface and keeping the young shoots above the soil surface. Mulching is useful in low rainfall areas. The seed germinates in the fruit, pushing out roots into the soil. The sprouted fruits produce new shoots in 8–10 days.

Alternatively, fruits can also be planted in polybags or pots till the sprouts have attained a length of l m. After one month these seedlings are transplanted in the field. About 2,000 sprouted fruits are required for planting one hectare. Then these pits are irrigated after planting.

Intercultural operations

Some type of trellis or support for the climbing vines is required. The trellis is about 2 m tall and needs to be solid to support the prolific growing vines. Most trellises in India are constructed about head high to facilitate walking beneath the vines for harvesting and other operations. When the plants start putting forth viny growth, they are staked. The shoots are tied with a jute thread or coir rope so that they can reach the bower or *pandal,* which are erected overhead at a height of 2 m from the ground level. Then the shoots are trailed on the *pandal.*

Chow-chow needs ample soil moisture for good growth. Irrigation is necessary during dry spells in the growing cycle. Do not allow the soil to waterlog, however. In areas with no irrigation, the crop is planted at the beginning of the rainy season. It requires large quantities of water and should be copiously irrigated in regions of low rainfall and during periods of drought. At no stage the plants must be allowed to have moisture stress. In some parts of Tamil Nadu it is grown under rainfed condition.

Hoeing and weeding are done as and when necessary. The remaining half dose of N (40 kg) can be applied at monthly intervals in 4 split doses from June or July. There should be sufficient moisture in the soil at the time of fertilizer application.

Every year after pruning the same quantity of FYM and NPK fertilizers should be applied. Since immature fruits are harvested, nitrogenous fertilizer should be applied frequently.

The vines start flowering 3–4 months after planting. Fruits mature about 35 days following pollination. At this stage, each pit is to be supplied with 200 g of urea and irrigated. In about 5–6 months, the vines cover the *pandal* and start yielding the fruits. In places, where mild climate prevails as in Bangalore, the crop bears fruits continuously and hence the plants are not pruned. In other regions, from the second year onwards the crop can be pruned. In hills, the vines are pruned back to ground level in January every year. The plants will sprout after winter and the fruits will be available from July-December. There are two fruiting seasons in a year and the vines are pruned at the end of each season, i.e. during December and May, leaving only a small portion of about 1.5 m of the stem.

Harvesting and yield

While an edible tuberous root forms below the crown, it is the fruit for which the plant is grown. Since it is a perennial, the best production is obtained 2–3 years after the plant is established. Both male and female flowers occur on the same vine. These flowers are visited by insects, both wasps and bees, which

facilitate pollination. The vines flower in 4–5 months after planting and the fruits are ready for harvest 28–32 days after pollination. Under commercial conditions the fruit is picked 2–3 times weekly when slightly immature, just before the seed protrudes from the apex. The peak season of harvest is between October-December and May-June.

Yields vary from 75–600 fruits/vine. Yields often decline after the third year. To control growth habit and for ease of harvest, vines may be trimmed after each harvest. The yield ranges from 250–350 q/ha.

Following harvest the fruits may be stored in edible condition for several weeks if wrapped in newspaper and kept cool (10–12°C). At room temperature, the fruit will shrivel and sprout. Fruits can be stored at room temperature for 1–2 weeks in places like Bangalore. The vines yield good crops for 3–4 years and moderate crop for another 2 years. After 5–6 years of planting, the vines are removed and fresh planting is established.

Seed production

Cultural practices followed for the seed production of chow chow crop are similar to that for vegetable production. However, the following aspects are to be considered:

Chow chow is monoecious (male and female flower parts in separate flowers but on the same plant) and is dependent on flower visiting insects for pollination. The fruits require about 30–35 days from pollination to mature sufficiently to harvest. Different varieties should not be grown together as they contaminate by cross pollination. Fields of chow chow varieties should be isolated with an isolation distance of 800–1000 m for foundation seed production and 400–500 m for certified seed production.

Rouging of off type plants should be done frequently. A minimum of three field inspections shall be made as under: i) before flowering; ii) during flowering and fruiting stage, and iii) before harvesting of the fruits.

Fruit maturation takes place between 30–40 days after pollination. Once mature, the germination takes place within the same fruit, hence it is known as endocarpic germination. If the fruits are not separated from the plant, the embryo develops inside the fruit, which is known as viviparity. For the purpose of planting material, fruits should be harvested at this stage.

All certified classes shall be produced from the viviparous fruits whose source and identity may be assured and approved by the Certification Agency. The seed material (viviparous fruits) shall be reasonably clean, healthy and shall conform to the characteristics of the variety. The fruits not conforming to varietal characteristics shall not exceed 0.1% and 0.2% (by number) for Foundation seed class and Certified seed class, respectively. ●

CHAPTER 15

Leguminous vegetables

BEANS AND PEAS belong to the family Fabaceae or Leguminoceae or Papilionaceae, which is a large and economically important family of flowering plants and this is commomly known as the legume family, pea family, bean family or pulse family. Legumes are dicotyledonous annuals or perennials. The Leguminosae (alternative name *Fabaceae*), the pea family, is one of the largest and most useful plant families comprising 17,000 species, distributed almost throughout the world. It includes many well-known vegetables particularly of temperate regions (beans, peas). The legume (or bean) family, which includes lentils, peas, beans, peanuts and soya, is hugely important as a source of food owing to its high protein content. The fruit of many species is a pod or legume that opens its 2 halves to disperse the seeds, but again there are many exceptions. Many legumes are able to fix atmospheric nitrogen through an association with root bacteria or have a close association with species of fungi, both strategies allowing them to colonise and grow in even the poorest soils, whilst also helping to stabilize and improve them. For this reason their economic importance is likely to grow as humans put more and more pressure on marginal lands. The Leguminous vegetable crops are, french bean (*Phaseolus vulgaris* L.), dolichos bean [*Lablab purpureus* (L.) Sweet], cluster bean (*Cyamopsis tetragonoloba*), lentil (*Lens culinaris*), Lima bean (*Phaseolus lunatus*), garden pea (*Pisum sativum*), vegetable soybean (*Glycine max*), winged bean (*Psophocarpus tetragonolobus*), vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis*), broad bean (*Vicia faba*), sword bean (*Canavalia gladiata*) and jack bean (*Canavalia ensiformis*). Their cultural requirements have few points in common. Pea is relatively hardy and can be grown under cooler condition, whereas the beans can tolerate relatively warmer weather. Beans and pea are capable of utilizing atmospheric nitrogen with the aid of bacteria found in the nodules on the roots of the plants. There are a number of cultivated species of beans in the plains, but the most commonly grown are french bean, cowpea, clusterbean and dolichos bean. These beans are commonly used as cooked vegetables either along with the green shell or without shell or as dry beans. They are rich in protein, carbohydrates, vitamin A and minerals.

Leguminous vegetables have been cultivated for more than 6,000 years in different parts of the world. Legumes for human consumption constitute about 5% of the cultivated crops. In countries like India where majority of the population

are vegetarians, leguminous vegetables serve as the major source of protein in the diet. Leguminous vegetables are used as fresh pod, immature seed and mature dry seed, and majority of these vegetables are also canned and frozen for the market. In developing third world countries, especially for the poor, the major protein source in the diet are vegetable legumes. Although leguminous vegetables are deficient in some of the sulfur-containing amino acids, they are well compensated when consumed with cereals. In some instances the leaves, tender shoots, and roots are harvested and used as vegetables.

Legumes are rather unique compared to other vegetables in that they can obtain free atmospheric nitrogen through their symbiotic association with the nitrogen fixing bacteria, *Rhizobium* or *Bradyrhizobium,* in legume root nodules. The nitrogen fixed in the root nodules are not only available to the plant but they also enrich the soil, in varying amounts, when the plants complete their life cycle.

Many leguminous vegetable plants contain toxic substances like trypsin inhibitor (soybean), rotenone (yam bean, *Pachyrhizus erosus* L.), and cyanogenic glucoside (dolichos bean).There are diverse ways by which the toxic effects of these vegetables can be eliminated rendering them safe for human consumption.

The beans and peas are self-pollinated crops and the fruit is called 'pod', botanically. Most of the cultivated varieties of the beans are vine types except the french bean where most of them are bushy type. All the above mentioned beans are annuals, whereas the plants of dolichos bean can be retained for about 2–3 years. In Karnataka and in other similar areas, beans can be grown all the year round.

Beans prefer warm weather and should not be grown in cooler climates. These crops should be grown in sites receiving full sun in well drained, fertilized soil. Beans can be planted in hills or rows depending on the type of beans grown. Beans come in numerous varieties consisting of both bush and pole types.

Bush beans are the easiest to grow, growing in the form of small, bushy plants, which are close to the ground. They need no support, require little care. These types of beans typically produce an earlier crop; therefore, successive plantings may be necessary for a continual harvest.

Pole beans are known as vine growing plants and will grow nearly anywhere. These types of beans require staking with supports that can be derived from items such as bamboo, string, a fence, trellis, or ladder. Sunflower or corn stalks can also be used for bean supports. Pole beans can be planted in hills or rows as well with the same spacing and thinning as bush beans. Before planting, however, it helps to incorporate the staking support for the beans to climb on once they have reached adequate size. Growing pole beans gives us the advantage of maximizing our space, and the beans grow straighter and are easier to pick.

FRENCH BEAN

French bean is probably a native of South America and is undoubtedly of ancient origin. These beans were brought from Central America and Mexico to Europe by the Spanish and Portuguese. French bean which is also called as common bean, snap bean, bush bean, field bean, garden bean, kidney bean, *rajmah,* is one


Fig. 10. French beans

of the most popular and widely grown vegetables in India. In Hindi it is known as *farash bean.* It is an excellent vegetable crop for green pods as well as for seeds.

Its major area is confined to hills, where it is grown for green pods. Punjab, Maharashtra, Jammu and Kashmir, Gujarat, Karnataka, Tamil Nadu, Uttar Pradesh, and Himachal Pradesh are the main states where it is being cultivated in a large scale. In India, the area under french bean is 118,000 ha with a production of 11,51,000 tonne and productivity of 9.8 tonne/ha (NHB, 2011).

The green immature pods are cooked and eaten as vegetable. Immature pods are marketed fresh, frozen or canned, whole, cut or french cut. 100 g edible fresh pods contain 91.4% water, 1.7% protein, 0.1% fat, 0.5% mineral water, 4.5% carbohydrates, 50 mg calcium, 28 mg phosphorus and 1.7 mg iron. 100 g dry seeds contain 9.6% water, 24.9% protein, 0.8% fat, 3.2% mineral water, 60% carbohydrates, 60 mg calcium, 433 mg phosphorus and 2.7 mg iron [Pal *et al.* 2004].

Botany

French bean (*Phaseolus vulgaris* L.) is a twinning plant belonging to the family Leguminosae and the genus *Phaseolus.* The beans tolerate a wide range of conditions in tropical and temperate countries, but do poorly in the very wet tropics where rain causes disease and flower drop. These plants are sensitive to diurnal fluctuations, folding their leaves together at night, while at dawn the leaves unfold towards the sun. Some cultivars yield yellow pods, but pods are more commonly green. Snap bean is a cultivar of french bean used as entire pods, other cultivars are eaten as immature green seeds, while the third group consists of dry beans.

Breeding

French bean is a self-pollinated crop. The breeding objectives in french bean are: for the improvement of vegetable types and dry bean types. The breeding procedures for the crop include hybridization, pedigree selection, single plant selection, bulk method of selection etc. In India the germplasm is maintained by the NBPGR, New Delhi; IIVR, Varanasi; and the Project Directorate of All Vegetable Crops, Varanasi. Several exotic varieties were introduced from the USA, Sweden, Mexico, Australia and Russia such as Contender, Giant Stringless, Jampa, Kentucky Wonder, Tender Green, Premier and others. In India, several improved cultivars are developed. They are pole types and bushy types which are early maturing, either round or flat and string less. Pant Bean 2 and YCD I are dual-

purpose types for both green pods and dry seeds. Local strains and some of the introduced varieties of French bean are available. Most of the genetic variations exist among the introduced varieties in the grower's field where no effort was made to maintain the genetic purity of a particular variety. Some 600 collections have been made in this crop. Some of the introduced varieties which performed well under large-scale production were recommended. A break-through was made by evolving a new variety 'Pusa Parvati' with the aid of mutation breeding. Some genetic studies with regard to economic characters have also been made (Nath *et al.* 2002).

Improved cultivars

Disease resistant cultivars

Contender: Plants bushy bearing light green, fleshy, oval and thick pods. High yielder than Giant Stringless in the plains. Maturity 50–55 days (first picking). Yield 80–95 q/ha. Resistant to powdery mildew.

Pusa Parvati: Developed at IARI, New Delhi. A bushy variety bearing light green, round and meaty pods. Maturity 45 days (first picking). Yield 80–85 q/ha. Resistant to powdery mildew.

Arka Anoop: Developed at IIHR, Bengaluru. A pedigree selection from Arka Bold × Arka Komal Plants bushy, photo-insenstive, resistant to both rust and bacterial blight. Pods long [17–18 cm] flat and straight. Duration 70 days and yield 200 q/ha.

Arka Bold: It is a bushy variety resistant to rust, Pods flat (1.5 cm width) medium long (15–17cm), stringless, smooth, light green, fleshy, with crisp texture. Pods. Yield 160 q/ha in 70 days. Released at IIHR, Bengaluru.

Pant Anupama: Selection in exotic germplasm. Pods medium long, round, straight, green It is resistant to rust, common bean mosaic and angular leaf spot. Developed at GBPUAT, Pantnagar.

Pant Bean 2: Pods flattish, round stringless. Both for green pods and dry seeds, cross between Turkish Brown × Contender. It is resistant to rust and common bean mosaic. Developed at GBPUAT, Pantnagar.

VL Boni- 1: It is a rust resistant variety. Pods medium long, Stringless, Pale green. Developed at Almora, U.P.

Bush cultivars

Arka Komal: Developed by IIHR, Bengaluru has green, fleshy, tender, long and straight pods. Produces 200–250 q/ha of green pods in 70–75 days. A very popular variety developed at IIHR, Bengaluru.

Arka Suvidha: Bushy, photo-insensitive, with medium long (15–17cm), stringless, smooth, light green fleshy pods. Pod yield 190 q/ha in 70 days. Recommended by IIHR, Bengaluru.

Arka Sharath: It is an improvement over Arka Suvidha. This is a photo-insensitive, bushy ring bean variety with medium long (15–16cm), stringless, smooth, and green fleshy pods. Pods are round on cross section and thin. This is released at IIHR, Bengaluru.

Jampa: A Mexican variety reported to be outstanding in performance in Maharashtra. The plant has a slight tillering habit. It flowers in about 47 days and the first picking is obtained after 2 months after sowing. In all, eight pickings within 40 days are obtained. The pod is flat, smooth, non-stringy and pale green. The seeds are black, smooth, small and flat. It is resistant to wilt.

Kashi Param: Developed by IIVR, Varanasi. Determinate plants. Yield 120–140 q/ha. Suitable for J & K, H.P, Uttarakhand, M.P, Maharashtra.

YCD 1: Selection from local type of shevroy hills. Pods slightly flat, green, Dual purpose. Developed at TNAU, Coimbatore.

Giant Stringless: A bushy variety. Pods green, long, slightly curved, meaty and string less.

Tender Green: Bushy type, bears light green, round and oval pods.

Pole type cultivars

Kentucky Wonder: A pole type with green, fleshy, round and slightly curved pods. Maturity 60–65 days (first picking). Yield 100–120 q/ha.

Pusa Himlata: Developed at IARI, New Delhi. A pole type. Pods medium long, round, straight, light green, meaty and stringless. Seeds white. Maturity 60 days (first picking).

Kashi Harittima: A Pole bean variety recommended for release at IIVR, Varanasi.

Climate and soil

French bean is a cool weather crop but can tolerate higher temperature than pea. The bean can be classified into long-day, short-day and day-neutral plants. Most of the French bean varieties are day neutrals and hence the day-length does not affect the seeding habit except some semi-vine varieties which are short-day types. This bean is sensitive both to frost and to very high temperatures. The plants drop their blossoms or pods in very hot-weather. The best pod is obtained at 15.6–21.1°C temperature. It can be grown on practically all types of soils except clay soils. Sandy and sandy loam soils are preferred for an early crop but heavier soils are desired for mid-season crop. It does not grow well on extremely acidic soils and is sensitive to high concentrations of aluminum and manganese. The most desirable *p*H is 5.3–6.0.

Cultural requirements

Sowing time: Since it is relatively a cool-weather crop, it is grown in winter. In the plains, the seed is sown from the middle of August-October, but where the winter and summer are not very severe, it can be sown up to February. In hills, it is sown during March-early May. In north-eastern and central zones it is sown at the end of October. The crop is sown in July-August, January-February or September-October in western or southern India.

Land preparation and sowing: The soil in the field is brought to fine tilth and 25 tonne/ha of FYM is incorporated into the soil before planting. Ridges and furrows are opened at 60 cm spacing. 30 kg N, 80 kg P and 60 kg K/ha are applied to the soil. A spacing of 60 cm × 120 cm is recommended for better aeration and

to minimize rapid spread of foliar diseases. Furrows are irrigated 2 days before sowing.

French bean is a shy nodulator and in order to encourage good nodulation and better nitrogen fixation, treating seeds with *rhizobium* culture is very essential. A day before sowing, treat the seeds with *rhizobium* mixed in jaggery solution and allow to dry in the shade for about 5–6 hours. Bean seeds are usually dibbled 2–3 cm deep, deep enough to give good coverage and sufficient moisture to promote fast germination and growth. For planting 1 ha of bush variety, about 75 kg of seeds are required. After sowing a light irrigation is given.

There are some pole or vine varieties which are spaced about 1 m apart from row to row and 8–10 cm from hill to hill within the rows. About 6 seeds are sown in each hill and later thinned out to 3–4 plants. It requires about 30 kg of seeds to plant 1 ha area.

For continuous harvesting of beans, 2–3 plantings should be made at regular intervals. The ridges on which sowing is done should be uniformly moist at the time of sowing to obtain good and uniform germination of seeds.

Intercultural operations

The field should be kept weed free up to 40 days after sowing. Generally hand weeding is followed to control the weeds, which also helps in loosening the soil. First weeding can be done 15 days after sowing and second weeding 30 days after sowing with earthing up operation. After 30 days of sowing 30 kg N/ha is top dressed.

Insufficient water at any growth stage will reduce yield and pod quality. It is most sensitive to water deficit during flowering and fruit development. For the good crop growth well timed furrow irrigation is effective. Wilting in the late morning indicates that the crop should be irrigated. As a general rule during the dry season, irrigate at an interval of 3–4 days during the first month after sowing, and then every 7 days interval until crop completion. The root zone of young transplants is shallow, so irrigation should be frequent and just enough to recharge the root zone. Beans are shallow rooted and sensitive to excessive moisture. A good yield is produced even in soils with low moisture content. However, optimum soil moisture should be maintained at the time of fruit set and pod development. It requires about 7–8 irrigations in spring season and 3–5 irrigations in winter.

As the vine grows, it requires staking in the pole type of beans which may be done with the help of poles. In fact, in some areas, pole beans are intercropped with other crops like maize to get self-staking. In bush varieties, no support is required.

Pest and disease management

Diseases

Major diseases are root rot caused by *Rhizoctonia solani.,* bacterial leafl blight, bean golden mosaic virus.

Foliar application of carbendazim (0.1%) or tricyclazole (0.06%) to control root rot caused by *Rhizoctonia solani*. Drenching infected plants with carbendazim

(0.1%) or copper oxychloridc (0.3%) is done when root rot is observed.

Common blight or bacterial leaf blight is caused by *Xanthomonas phaseoli.* The symptoms of the disease are the water soaked spots which appear on the lower side of the leaf. These spots enlarge and coalesce and turn brown giving a burnt appearance. Insects like grasshopper and Mexican bean beetle transmit this disease. Use of disease free seed, long rotation and use of resistant varieties are the control measures. This can be controlled by spraying streptocycline (0.03%) or copper hydroxide (0.2%).

Bean golden mosaic virus disease causes stunting of the plants, mottling and leaf malformation. The main insect vectors are species of Aphis. The only satisfactory method is use of resistant varieties. Foliar spray of acephate (0.15%), followed by spray of imidadoprid (0.033%) or metasystox (0.05%) gives effective control.

Insect pests

Major insects are stem fly, leaf miner, thrips, red spider mites. The maggot of stem fly (*Ophiomyia phaseoli*) causes drying of the plants when enters into the stem. Monitor the plants for stem fly adult activities, puncture marks and petiole mining soon after germination. As soon as a few adults of stem fly (small housefly like insects) are noticed hovering over the crop, spray endosulfan 35 EC 2 ml/litre, or acephate 75 WP @ 0,75 g/litre of water. Second spraying is given when on an average 5 leaves/10 leaves have petiole mining symptoms or at 15 days after sowing.

This will also take care of leaf miner also. For leaf miner, do not repeat sprays again and again, as it will increase pest population.

Thrips infested leaves turn pale and drop. Infested pods exhibit silvery white colour. Spraying with dirnethoate (2 ml/litre) or lamda cyhalothrin (1 ml/litre) is effective in controlling this pest.

Red spider mites are the sucking pests. Spray acaricide like dicofol (1.5 ml/litre) or wetable sulphur (2.5 g/litre). Spray underside of the leaves thoroughly.

During September-October months after the onset of northeast monsoon hoppers become very serious causing withering of the foliage and plants. The pest can easily be controlled by spraying any systemic insecticide.

Harvesting and yield

Crop will be normally ready for first picking by 40–45 days after sowing depending on the variety and season of cultivation. Harvest during cool periods, such as late afternoon or early morning. Immediately after harvest shift the produce to the shade. Further, there will be 2–3 pickings to be done at 4–5 days interval. About 150–200 q/ha of marketable yield can be obtained. Yield in pole beans is almost double of the bush varieties. The pods can be stored for about 15–20 days at 2–4°C with 60–70% relative humidity.

Dry beans are harvested when a large percentage of the pods are fully ripe but before they become very dry and begin to shatter. They are cured for 2–3 weeks and then threshed by bullocks or by machines. The yield of dry bean seeds varies from 15–16 q/ha.

Seed production

Cultural practices for seed crop is similar to that for vegetable crop or commercial crop. However, the following aspects need to be taken care of:

Isolation: Members of the bean family are self-pollinating and crossing is uncommon. Different bean varieties do not commonly cross-pollinate each other. But varieties can be separated by 50 m and 25 m distance for foundation seed and certified seed production, respectively, to insure purity.

Roguing: Constant roguing of off type plants and plants affected by diseases like anthracnose, bacterial blights and mosaic must be done right from the beginning. Affected plants should be removed as a whole immediately on sight.

Seed harvesting, threshing and drying: Allow pods to dry on the vines before picking and shelling. Pick beans for seed after the pods are ripe and have dried on the plants. Don't allow dried pods to get rained on as the beans may quickly mildew or sprout in their pods. Pods are harvested when they have turned yellow but have not been completely dry and seeds in the pods are firm, well developed and have just began to break free from the inside of the pod. Two harvesting operations may be necessary before leaving the crop for seed production. Harvesting is best done in the morning to avoid shattering loss.

Harvested pods should be dried in the sun and kept stacked under cover for 1–2 weeks for curing. Pods are then threshed by hand. When very dry many pods will split on their own to drop their seeds; the rest can be easily crumbled in the hands and the finer chaff blown away after removing the big pieces. A seed yield of 1000–1200 kg/ha can be obtained.

Seeds with a low moisture content are extremely liable to injuries during threshing. It may result in bald headed seedlings which are very less productive. If splitting of seed occurs, it fails to germinate at all. Soon after threshing seeds should be cleaned and dried. Drying to seed moisture content below 11% will be necessary for temporary storage in ventilated sheds within the RH of 75%. For storing in moisture proof containers seed moisture content should be reduced to 9%. Reduction of seed moisture content below this level is not required. If done, it will cause high percentage of hard seeds especially in white seeded varieties and increases susceptibility to cracking. Bean seeds, properly dried and stored, will keep for 4 years.

DOLICHOS BEAN

Dolichos bean, is supposed to have originated in India. Since wild forms of beans are found in India, it is probably considered as the centre of origin. Dolichos bean is known as hyacinth bean, Indian bean, *sem.* It is grown all over the country but compact large acreage for commercial production is uncommon. 65

It is an important leguminous vegetable of India. It is very popular in Maharashtra, Tamil Nadu, Andhra Pradesh, Uttar Pradesh and North-east India.

It is mainly grown for its tender green pods. Mature fresh green seeds are also used as vegetable and dry-seeds as pulse. It is primarily grown for green pods which are cooked as vegetables like other beans. The dry-bean seeds are also collected for various vegetable preparations. The pods, seeds and leaves differ greatly in size, shape, colour and texture. The mature seeds, especially dark

coloured ones, contain a trypsin inhibitor and must be boiled before eating. The trypsin inhibitor is broken down by heat and a toxic cyanogenic glucoside, soluble in cooking water, is removed. It is also grown as pulse crop as field bean.

Dolichos is rich in protein, minerals, vitamins and fibre. Its fresh green pods contain 86.1% moisture, 3.8% protein, 6.7% carbohydrate, 0.7% fat, 0.9% mineral matter, 312 IU vitamin A. It is also a good source of vitamin B and C.

Botany

Hyacinth bean or Indian bean or Dolichos bean, [*Lablab purpureus* (L.) Sweet; syn. *Dolichos lablab* L.] belongs to the family *Leguminosae.* Dolichos bean is a herbaceous perennial plant but cultivated as an annual. The cultivated strains with good vegetable pod qualities are vine type. The vine needs to be trained on trellis or on any other support. Like pole bean varieties, these may be planted 1–1.5 m apart between the rows and 1 m apart between the hills with in the rows. It is an annual, but the plant can be retained for 2–3 years in the kitchen gardens. There are two types of Dolichos bean, which are commonly cultivated:

1. *Lablab purpureus* var. *typicus:* The pod walls are parchmentless; hence whole pod is used in cooking. Majority are pole types with varied pod size and colour. Few bush types have been developed in India through breeding. Both pole types and bush types are commercially grown.
2. *Lablab purpureus* var. *lignosus:* It is also known field bean. Here, pod walls contain high amount of fibre and hence whole pod is unsuitable for consumption. Only mature green seeds and dry seeds (pulse) are edible. It is very commonly cultivated as rainfed crop between June to January particularly in states like Karnataka and Andhra Pradesh. In this group also, both pole and bush types are available.

Breeding

Though it is grown all over the plains of India, not much research work has been carried out either to maintain the local useful strains or to improve upon the local strains for pod quality and yield. The genetics of some of the economic characters have been studied. A vine variety, 'Pusa Early Prolific' was recommended by IARI. It bears early long thin pods in bunches and is suitable for sowing both as early spring and autumn crop. Some of the promising strains have also been reported from Coimbatore. In Karnataka 'Hebbal Avare' of UAS, Bengaluru is popular and grown commercially. At IIHR, Bengaluru, two line, viz. 'IHR 93' and 'IHR 140' were reported to be rust resistant and high yielders with good pod quality. Breeding photo-insensitive varieties both as vegetable and seed is gaining popularity and two varieties Arka Jay and Arka Vijay have been developed and recommended for commercial cultivation (Nath *et al.* 2002).

Improved cultivars

Bush type cultivars

Arka Jay: Developed at IIHR, Bengaluru, using backcross and pedigree

selection involving the cross Hebbal Avare and IIHR 93. Plants dwarf, bushy, erect and photo-insensitive. Flowers are purple and pods long, light green, slightly curved without parchment. It is a vegetable type with excellent cooling quality. Resistant to moisture stress and heat. Crop duration 75 days. Pod yield 120 q/ha. Recommended for Karnataka.

Arka Vijay: Developed at IIHR, Bengaluru. Plants dwarf, bushy erect and photo-insensitive, leaves dark green, flowers white, pods short dark green, seeds bold, pods characteristic aroma, with parchment. Vegetable type with tolerant to moisture stress and heat. Duration 75 days and pod yield 120 q/ha. Recommended for Karnataka.

Arka Soumya: A high-yielding variety developed at IIHR, Bengaluru. Plants are medium tall, 50% flowing in 40 days and pods are ready for harvest in 55 days. Pods are slender (1.0 cm width), medium long (13–15 cm), yield 120 q/ha.

Arka Sambhram: A high-yielding variety developed at IIHR, Bengaluru. Plants are medium height, 50% flowering in 40 days and pods are ready for harvest in 55 days. Pods are flat, light green, medium long (13–15 cm), medium width (1.5 cm), yield 120 q/ha.

Arka Amogh: A high-yielding variety developed by IIHR, Bengaluru. Plants are medium height, 50% flowering in 40 days and pods are ready for harvest in 55 days. Pods are similar to Arka Jay, yield 120 q/ha.

Pusa Sem - 2: Developed at IARI, New Delhi. Pods dark green, first picking in 120–125 days, yield 150 q/ha.

Pusa Sem - 3: Developed at IARI, New Delhi. Pods green 15 cm long first picking in 115–120 days, 170 q/ha.

Thar Kartiki: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. It takes about 75 days to flowering after sowing. First fruit harvest takes place about 94 days after sowing. Average pod yield is 1.8 kg/plant giving an yield of 108 q/ha.

Thar Maghi: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. It is high yielding. Takes about 93 days for first harvesting as compared to about 100 days in cultivar AHDB 3. Average yield is 113.25 q/ha.

Pole type cultivars

Pusa Early Prolific: Developed at IARI, New Delhi. It is a pole type. Light green pods. Duration 200–215 days. Yield 140 q/ha.

Swarna Utkrisht: This is a pole type variety released by ICAR-RCER, Patna. Recommended for cultivation in Uttar Pradesh, Jharkhand, Bihar and Punjab. Time of sowing: June–July. Yield: 350–400 q/ha.

Apart from the above varieties, TNAU, Coimbatore has released Co-1, Co-2, Co-3 to Co-12; JNKVV, Jabalpur has released JDL 17, JDL 53; and CSAUA, Kanpur, has released KDB 403 and KDB 405; UAS, Bengaluru, has released Hebbal Avare 1, Hebbal Avare 2, Hebbal Avare 3, Hebbal Avare 4.

Climate and soil

Dolichos bean is relatively a cool season crop. Sowing is done in July-August.

It can be kept alive in summer to provide pods in the next season but bearing is poor. New plantings should be done every year. Some of the strains are highly drought resistant and are often grown along with castor or sorghum. It fruits from the beginning of the season and continues to give green pods through-out winter and spring. Heavy flower shedding has been reported to be a problem and some of the varieties have a relatively high pod set than others. It requires short-days to initiate flowering. It thrives well under wide range of soils if proper drainage is provided. It performs best on fertile sandy loam soils with good internal drainage and moderate organic matter content. Soils with a *p*H between 5.8 –6.5 are best.

Cultural requirements

Sowing time: The bush types which are photo-insensitive, can be grown during all the three seasons. The ideal time for sowing the bush varieties is the first fortnight of June and October and February.

Pole types however are photosensitive. Hence, they are sown usually during June-July and fruiting is between November and January and sometimes extending up to February. Pole types survive during summer season and again the crop starts giving fresh leaves by June-July of subsequent year.

Land preparation and sowing: Bring the soil to fine filth by ploughing three to four times followed by cross harrowing and cultivating. The soil should be friable without any clods. Apply 10 tonne/ha of FYM. Prepare ridges and furrows at 60 cm distance for bush types and at 1 m distance for pole types. The ridges can be 3–4 m long. Apply 25 kg N, 60 kg P, 50 kg K/ha in the furrows and cover with soil. Irrigate the furrows two days before sowing. Within the rows, between plants spacing of 10 cm for bush types and 75 cm for pole types is maintained.

Open slender shallow furrows on one side of the ridges. Dibble seeds in the shallow furrows. Cover seeds with thin layer of soil. A seed rate of 60 kg/ha for bush varieties and 25–30 kg/ha for pole varieties is required.

Intercultural operations

Irrigate the plot two days after the sowing and thereafter at 4–5 days intervals depending upon availability of soil moisture. Keep the plots weed free. Two hand weedings before earthing up and thereafter fortnightly weeding may be done. Top dress with 25 kg N/ha and earth up 25–30 days after sowing.

Pest and disease management

Diseases

Root rot or Collar rot: The disease can be controlled by drenching one week old seedlings with captan 50 WP (0.2%).

Powdery mildew: Initially white powdery patches are formed on both sides of the leaves which gradually spread to all the parts of plant. It commonly occurs during cool and dry weather conditions. The crop may be sprayed with wettable sulphur at 2 g/litre.

Rust: Coffee powder like pustules appear on the lower surface of the leaves. In severe cases leaves turn yellow and fall. Control this disease by spraying wettable sulphur (2 g/litre)

Anthracnose: Symptoms first appear as regular to irregular shaped small brown to black spots. On leaves and petioles. These spots enlarge, forming irregular patches of dead tissue. The central portion of the disease spot on leaves become dry and papery in nature, and form characteristic hole known as 'shot hole' symptom. On pods elongated brown to black lesions develop which enlarge, coalesce and form the sunken and black lesions. Spraying of mancozeb 75 WP (0.2%) or benomyl 50 WP (0.1%) will control this disease.

Bacterial blight: The disease usually appears when the humidity is high. Water soaked lesions appear on the affected leaves. They enlarge and coalesce if humidity is high. Older lesions are brown and papery, especially on the pods. For controlling this disease spray copper oxychloride 50 WP (0.3%).

Dolichos yellow mosaic virus: The disease is transmitted by white fly. Affected leaves show bright yellow patches. Spraying 2 ml of monocrotophos in one litre of water will control the white flies which spread the virus.

Insect pests

Major insects are pod borers, ahids and bugs spray of endosulfan 0.07% or chlopyriphos (0.05%) at 10–15 days interval to control pod borers. Spray dimethoate (2 ml/litre) or acetamiprid (0.5 mill) to control aphids. Dust endosulfan 4% or spray with indoxacarb 0.5 ml/litre if the incidence of bugs is high.

Harvesting and yield

Pods can be harvested when they are mature, tender and are fully grown. In field bean green seeds should be mature and bold before harvesting. In bush varieties, green pod yield ranges from 100–120 q/ha and in pole varieties, it ranges from 150–200 q/ha.

Seed production

As in french bean.

COW PEA

Cowpea is probably a native of Central Africa. Africa is considered as the primary centre of origin. Of 170 species of genus *Vigna*, 120 are in Africa, 22 in India and Southern Asia and the rest in America and Australia. The crop spread from Africa to Asia and Europe through Egypt. It was introducted by the Spaniards into the West Indies in the 16th century and was taken to the United States around 1,700. Now, cowpea is widely distributed throughout the tropics and subtropics (Peter, 1998).

It is a nutritious leguminous crop low in anti-nutritional factors. It has a wide range of ecological adaptations and could be more widely grown. In fact, it probably has the greatest potential among all food legumes in the semi-arid to sub-humid tropical areas. The typical vegetable cowpea is

characterized by long pods (<30 cm), stringless pods, fleshy pod pericarp, thin and long seeds, and higher ratio of monosaccharide: polysaccharide. Pole and bush types are available in vegetable cowpea (Peter, 1998). In Hindi it is known as *lobia.*

It is mainly grown for its long green tender pods used as vegetable and its seeds as pulse. The pods and seeds are highly nutritious as they are rich in protein, calcium, phosphorous, iron and vitamins. On dry weight basis it contains 23.4% protein, 1.8% fat and 60.3% carbohydrates. It is a short duration, drought resistant crop. It produces heavy vegetative growth and covers the ground so well that it checks erosion (Pal, 2004).

Botany

Cowpea [*Vigna unguiculata* subspecies *sesquipedalis*(L.) Fruw.] belongs to the family Leguminosae. The cultivated cowpea is polymorphic and consists of *Vigna sinensis* subsp. *sinensis* (syn. *V. unguiculata* var. *radiata*; *Dolichos sinensis* L.), *V.catjang* (syn.*V. sinensis* var. *cylindric; V.unguiculata.* var. *Cylindrica*) and *sesquipedalis,* (syn.*V. unguiculata* var. *sesquipedalis, Dolichos sesquipedalis*). It is stated that *V. sinensis* and *V. catjang* differentiated from a common ancestroral stock and *V. sesquipedalis* is a later selection from *V. sinensis*. Recently all the cultivated species have been placed under a single species *V. unguiculata* (L.) Walp.

Five sub-species of *V. unguiculata* have been recognised. These are *V. unguiculata* (L.) Walp. Subsp. *unguiculata* (syn.*V. unguiculata* var. *radiata*): *V. unguiculata* subsp. *cylindrica* (L.) Verdc; *V. unguiculata* subsp. *sequipedalis* (L.) Verd; *V. unguiculata* subsp. *dekindtiana* (Harms) Verd; *V.unguiculata* subsp. *mensensis.* The first three sub-species are cultivated ones and the rest are wild species. The related species are *V. luteola. V. nilotica* and *V. marina* (Burma) Merr. The cyto-taxonomy of cowpea is relatively simple being uncomplicated by polyploids. It is a true diploid with 2n=22. Cytotaxonomic studies on *Vigna sinensis* (L.) Savi: *V. catjang* (Bur. M) Walp. and *V. sesquipedalis* (L.) Fruw, popularly known as cowpea, catjang bean and asparagus bean, have revealed that the three cultivated species could be easily crossed among themselves. The hybrids among them were fertile like intervarietal hybrids. Chromosome numbers of each of the three cultivated species were found to be 2n=22. As mentioned elsewhere all the above cultivated species are put under *Vigna unguiculata* (Peter, 1998).

Breeding

The *Vigna unguiculata* (L) Walp. cultivar group *sesquipedalis*, the yard long been (synon: string bean, asparagus bean) is a type of cowpea used as vegetable. The dual purpose cowpea [*Vigna unguiculata* (L). Walp. cultivar group *cylindrica]* is used both as a pulse as well as a vegetable. Much emphasis has been given to the exclusively pulse type (*Vigna unguiculata* var. *radiata*) and to the dual purpose type (*Vigna unguiculata* var. *cylindrica*). Less attention has been given to the vegetable cowpea.

Cowpea is a self-pollinating crop and has cleistogamous flowers. In India, several cultivars were developed by hybridization, pedigree method of selection,

bulk pedigree selection, backcrossing, pureline and mass selection. Initially, a few improved varieties were selected from introductions of exotic varieties/ germplasms of Southeast Asian and Western countries. The variety 'Pusa Phalguni' was selected from the Canadian variety 'Dolique Du Tonkin', whereas 'Pusa Barsati' was selected from a variety from the Philippines. 'Pusa Dofasli' was evolved by crossing 'Pusa Phalguni' and a Philippine selection at IARI. Genetics of some of the economic characters and interspecific hybridization has also been studied (Nath *et al.* 2002).

Improved cultivars

Disease resistant cultivars

Pusa Komal: Developed at IARI, New Delhi. Bushy, suitable for growing during spring-summer and rainy seasons. Pods light green, thick, fleshy and 20–22 cm long. Resistant to bacterial blight disease. Yield 120–130 q/ha. It is a photo insensitive variety.

Pusa Sukomal: This is released by IARI, New Delhi. Resistant to golden yellow mosaic virus and leaf spot diseases. Average yield 60 and 65 q/ha during summer and *kharif* seasons, respectively. Maturity 55–60 days.

C-152: Resistant to root knot nematode tall erect plants, 90–100 days for maturity, oblong light brown seeds. Developed by IARI New Delhi.

Kashi Shyamal: Developed by IIVR, Varanasi. Dwarf bushy varieties. Suitable for both *kharif* and zaid season. Yield 48 days after sowing. Pod yield 70–80 q/ha and the plants are tolerant to golden mosaic virus recommended for Punjab, Uttar Pradesh, Bihar and Jharkhand.

Kashi Gauri: Developed by IIVR, Varanasi. Dwarf, bushy type, photo-insensitive, Suitable for spring summer and rainy season. Resistant to golden mosaic virus and leaf spot diseases. Yield 10–12 tonne/ha green pods. Duration 40–48 days.

Swarna Harita: Released by ICAR-RCER, Patna. Tolerant to cowpea mosaic virus and rust. Yield: 300–350 q/ha.

Swarna Suphala: Released by ICAR-RCER, Patna. Resistant to rust and cowpea mosaic virus. Yield: 250–300 q/ha.

Bushy/Dwarf cultivars

Pusa Phalguni: Developed by IARI, New Delhi. Bushy dwarf variety suitable for sowing in February–March in the northern plains. Pods dark green, erect and 10–20 cm long. Maturity 60 days (first picking). Yield 70–75 q/ha.

Pusa Barsati: Developed by IARI, New Delhi. Suitable for growing during rainy season. Pods light green, 26–28 cm long and pendant. Maturity 45 days (first picking). Yield 70–75 q/ha.

Pusa Dofasli: Developed by IARI, New Delhi. Bushy, suitable for growing both in spring-summer and rainy seasons. Pods light green and about 18 cm long. Maturity 45–50 days (first picking). Yield 75–80 q/ha. It is a photo-insensitive variety.

Pusa Rituraj: Developed by IARI, New Delhi. Bushy, 40–50 days for first

picking, light green pods, seeds brown. Photo-insensitive variety.

Cowpea 263: Bushy dwarf, medium green pods, 45–50 days for first picking. Developed by PAU, Ludhiana, tolerant to mosaic virus.

Narendra Lobia 1: Bushy, 45–48 days for first picking, green pods and bold seeds.

Arka Garima: Developed by IIHR, Bengaluru. Plants are tall, vigorous, bushy with small vines and photo-insensitive. Leaf colour light green, flowers purple, pods light green, long, thick, fleshy and stringless. Suitable for vegetable purpose. Tolerant to heat and moisture stress. Duration 90 days. Pod yield 18 tonne/ha. Recommended for H.P, Maharashtra, Karnataka, Kerala.

Arka Suman: Developed by IIHR, Bengaluru. Plants erect, bushy, photo-insensitive, pods medium long, fleshy, crisp without parchment, Duration 70–75 days pod yield 18 tonne/ha. Recommended for Karnataka.

Arka Samrudhi: Developed by IIHR, Bengaluru. Plants erect, bushy photo-insensitive, early with pods above the canopy. Pods green, medium thick, medium long, round, fleshy without parchment. Good cooking qualities. Duration 70–75 days. Yield 19 tonne/ha. Recommended for U.P, Bihar, M.P and Maharashtra.

Pole type/yard long bean cultivars

NS 634: This variety is developed by Namdhari Seeds Pvt. Ltd., Bengaluru. Indeterminate plants start flowering from 38–42 days after sowing. Dark green pods are long (45–50 cm), thin, fleshy. High yeilding variety of 90–95 days duration. Suitable for rainy and mild winter season.

NS 636: This variety is developed by Namdhari Seeds Pvt. Ltd., Bengaluru. Indeterminate plants with twining habit. Flowering commences from 40–45 days after sowing. Pods are long (55–60 cm), light green, tender, fleshy and sweet in taste. The variety is suitable mainly for rainy season and also for winter where it is mild.

NS 620: This variety is developed by Namdhari Seeds Pvt. Ltd., Bengaluru. Indeterminate plants with twining habit. Flowering commences from 40–45 days after sowing. Pods are long (55–60 cm), light green, tender, fleshy and sweet in taste. The variety is suitable mainly for rainy season and also for winter where it is mild.

Climate and soil

It is a warm season crop and cannot stand cold-weather. It can be grown both in the spring and rainy seasons in the plains, but it cannot tolerate heavy rainfall. Different varieties respond differently to temperature and day-length and hence there are distinct varieties for spring and rainy seasons. It can be grown on practically all types of soils like french bean.

Cultural requirements

Sowing time: The ideal time for sowing is the first fortnight of June, October and February. Usually two crops of cowpea are taken in the plains but in places like Bengaluru where summer and winter are not very extreme, it can be grown throughout the year. It is usually sown in December-January in southern plains

and February-March in the northern plains during the spring time. For the rainy season crop, the sowing is done in June-July all over the plains.

Both pole and bush type varieties are available in cowpea. Pole types are photo-sensitive, need staking and require wider spacing like *sesquipedalis* types (yard long bean), whereas, the bush varieties are dwarf, compact and do not require staking. They are photo-insensitive and hence, can be grown round the year.

Land preparation and sowing: Bring the soil to fine filth by ploughing three to four times followed by cross harrowing and cultivating. The soil should be friable without any clods. Apply 10 tonne/ha of FYM. Prepare ridges and furrows at 60 cm distance for bush types and at 1 m distance for pole types. The ridges can be 3–4 m long. Apply 25 kg N, 60 kg P, 50 kg K/ha in the furrows and cover with soil. Irrigate the furrows two days before sowing. Within the rows, seed to seed/ plant to plant spacing of 15 cm is maintained.

Open slender shallow furrows on one side of the ridges. Dibble seeds in the shallow furrows. Cover seeds with thin layer of soil. A seed rate of 25 kg/ha for bush varieties and 10–12 kg/ha for pole varieties is required.

Intercultural operations

Irrigate the plot two days after the sowing and thereafter at 4–5 days intervals depending upon availability of soil moisture. Keep the plots weed free. Two hand weedings before earthing up and thereafter fortnightly weeding may be done. Top dress with 25 kg N/ha and earth up 25–30 days after sowing.

For pole types, about 150–175 cm high trellis are to be provided for every two lines of a bed, trellis to be created in such a way that the tops of sticks are bounded together to form a triangular structure with the bed. Sufficient sticks to be provided to help the plants to climb up.

Pest and disease management

Diseases

Common blight or bacterial leaf blight: It is caused by *Xanthomonas phaseoli*. The symptoms of the disease are the water soaked spots which appear on the lower side of the leaf. These spots enlarge and coalesce and turn brown giving a burnt appearance. Insects like grasshopper and Mexican bean beetle transmit this disease. Use of disease free seed, long rotation and use of resistant varieties are the control measures. This can be controlled by Seed-treatment with streptocycline (100 ppm), followed by spraying streptocycline (0.03%) or copper hydroxide (0.2%).

Powdery mildew: Initially white powdery patches are formed on both sides of the leaves which gradually spread to all the parts of plant. It commonly occurs during cool and dry-weather conditions. Foliar application of carbendazim (0.1%) or dinocap (0.1%) is effective in control of powdery mildew disease.

Rust: Coffee powder like pustules appear on the lower surface of the leaves. In severe cases leaves turn yellow and fall. Spray chlorothalonil (0.2%) to control rust.

Insect pests

Major insects are stem fly, aphids, pod borers, flea beetles, bugs, leaf hoppers.

The maggot of Stem fly (*Ophiomyia phaseoli*) causes drying of the plants when enters into the stem. Monitor the plants for stem fly adult activities, puncture marks and petiole mining soon after germination As soon as a few adults of stem fly (small housefly like insects) are noticed hovering over the crop, spray endosulfan 35 EC 2 m1/l, or acephate 75 WP @ 0,75 g/l of water. Second spraying is given when on an average 5 leaves/10 leaves have petiole mining symptoms or at 15 days after sowing.

This will also take care of leaf miner. For leaf miner, do not repeat sprays again and again, as it will increase pest population.

Pod borers feed on the floral parts and on pods. Therefore first spray has to be given at flower bud stage. Spray neem seed powder extract 4% or neem soap 1% or cypermethrin 25 EC @ 0.5 ml/l as soon as eggs are noticed on flower buds. Spray of endosulfan 0.07% or chlopyriphos (0.05%) at 10–15 days interval to control pod borers.

Spray dimethoate (2 ml/l) or acetamiprid (0.5 m) to control aphids.

Spray indoxacarb (0.5 m1/1) if the incidence of bugs is high.

Harvesting and yield

As in other beans, the tender pods are harvested for marketing purpose. Frequent harvesting should be done at 4–5 days interval, before the pods become fibrous and unfit for the market. The marketable pods are available from 45 days in the early varieties to 100 days in the late varieties. Green pod yield ranges 150–200 q/ha.

Seed production

Cultural practices for seed production are similar to that for vegetable production. Since cowpea or yard long bean is a self-pollinated crop, relatively short isolation distance has been recommended. It is important that adjacent cultivars should be at least 50 m apart with distance increased to at least 100 m for stock seed production.

Constant roguing for off-type plants and plants affected by mosaic or other diseases should be done right from the beginning. Affected plants should be removed as a whole immediately on sight.

Pods are harvested when they have turned yellow but have not been completely dry and seed in the pods are firm and well developed and have just begun to break free from the inside of the pod. Harvesting should be done as soon as the pods are ready to avoid any damage due to sudden rain. Two-three harvestings will be necessary. Harvested pods are dried in the sun and threshed by hand with care to avoid loss due to breaking injuries. Seeds are cleaned and dried soon after threshing. Drying seed to a moisture level below 15% will be necessary for temporary storage in ventilated sheds. For long storage, moisture content should be around 11%. Under appropriate care and management, seed yield should be about 1000–1200 kg/ha

CLUSTER BEAN

Fig. 11. Custer bean

The origin of cluster bean is not definitely known but it has been grown since a long time in India, Africa, Peru and Java, where it is quite adapted for commercial production. In Hindi it is known as *guar, guwar, guvar bean.* It is a very hardy type of crop and survives well in the tropical plains. It is grown very commonly in the northern plains and an appreciable area has come under this crop in southern plains also.

The pod is primarily used as a vegetable. Some of the fodder varieties are also available in different parts of the country. In the low rainfall areas of northern plains, it is the most common poor man's vegetable crop. Of late, the gum from its seed is becoming an important commodity in international trade. The gum is a major component of adhesives including those widely used on postage stamps. The gum is used to impart smoothness and stability to bakery products, used as a foam stabilizer in beer, used to impart luster to silk and other fine textiles and many other uses. Fresh pods contain 82.5% water, 9.9% carbohydrates, 3.7% protein, 0.2% fat, 2.3% fibre and 1.4% mineral water [Pal, 2004].

Botany

Cluster bean (*Cyamopsis tetragonoloba*) belongs to the family Leguminosae. It is an annual legume and the source of guar gum. It grows best under conditions with frequent rainfall, but tolerates arid conditions well. Cluster bean is a bushy type herbaceous annual. Some of the varieties have single stem where the fruits are borne in clusters, where as some other varieties produce branches and need more wider spacings for cultivation.

Breeding

A good number of useful indigenous strains are available in the northern plains. Some of the outstanding strains have been purified and selected as commercial varieties. The variety 'Pusa Sadabahar' was selected from a local strain of Rajasthan, whereas 'Pusa Mausami' was selected from another local strain. 'Pusa Navbahar' was evolved at IARI by crossing the above two varieties with an ability to crop well in both spring and rainy seasons. Genetics of some of the economic characters have also been studied (Nath *et al.* 2002).

CHES-1 developed at Central Horticultural Experiment Station, Godhra; a regional station of IIHR, Bengaluru by individual plant selection and progeny testing from an original line, 'Rajasthan local' has erect, single, stemmed plants, bearing from base at first true leaf at ground level in clusters upto 35 with 9–11 pods per cluster at short internodes. Pods are medium long, thin, smooth, green, non

fibrous and stringless, yielding 88–103 q/ha. While CHES 116 × 117-1 F_6 developed by inter varietal hybridization and pedigree selection has tall plants with medium thick, single stem, bearing from base at first true leaf at ground level in clusters up to 30 with 10–12 pods per cluster at short internodes. Pods are long, tender, green, smooth and yielding 88–96 q/ha. Both the selections, are photo-insensitive, drought tolerant, moderately resistant to major diseases like bacterial blight, powdery mildew and alternaria leaf spot. Best suited for inter and mixed cropping or nutrition garden at closer spacing of 50 cm × 15 cm with a crop period of 75–85 days. They out yielded the check variety Pusa Navbhar by 56.16 and 52.15%, respectively. CHES-1 has been identified for release as 'Goma Manjari' during 1996. Cluster bean is mostly self-pollinating and the breeding methods like pure line selection and hybridization are commonly used for its improvement.

Improved cultivars

Goma Manjari: This variety has been released by CHES (IIHR), Godhra. It is resistant to powdery mildew, bacterial blight and leaf spot diseases.

Pusa Mausami: Developed by IARI, New Delhi. Pods attractive, smooth, bright green and 10–12 cm long. First picking in 65–80 days after sowing. Suitable for rainy season.

Pusa Sadabahar: Developed by IARI, New Delhi. A non-branching type. The pods green and 12–13 cm long, tender and fibreless. First picking in 45–55 days after sowing. Suitable for both summer and rainy seasons.

Pusa Navbahar: Developed by IARI, New Delhi. Pods 15 cm long and of better quality. A non-branching type. Suitable for both summer and *kharif* seasons.

P-28-1-1: Smooth, green and long pods. A photo-insensitive variety, flowers in 30–32 days in summer and 40 days in *kharif.* Suitable for both summer and *kharif* seasons.

Sharad Bahar: This variety is released by NBPGR, New Delhi. This is an high yielding variety with good pod quality.

Thar Bhadavai: Released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. High yielding cultivar having yield of 65–125 q/ha. Average yield per plant is 75 g/plant and it bears around 9 clusters/ plant. Average plant height is 67–70 cm, first harvest stakes place around 59 days after sowing.

Climate and soil

The cluster bean is a warm season crop and grows well in summer as well as in the rainy season in the plains. It is very hardy and relatively resistant to drought. In regions with high summer temperature and low rainfall it produces an excellent crop where no other important vegetable crop could be grown successfully. It is adapted to all types of soils but thrives best in well drained, sandy loam soil. It can be grown in alkaline sandy loam soil. Soil *p*H 7.5–8.0 is good for the crop.

Cultural requirements

Sowing time: Sowing is done during February-March, June-July and December-January. The crop is sown during December –January in the southern plains,

February-March in the northern plains and June-July all over the plains.

Land preparation and sowing: Plough the field to fine tilth and form ridges and furrows at 45 cm or 60 cm apart. Farmyard manure (FYM) is applied @ 25 tonne/ha. 25 kg N, 50 kg P, 50 kg K/ha should be applied in the furrows and covered with soil. Irrigate the plot 2 days before sowing. Sowing distance between the plants in a row is 10–20 cm.

Treat the seeds with rhizobium @ 600 g/ha using binders like rice gruel. Dry the treated seeds in shade for 15–30 minutes before sowing. Dibble the seeds to a depth of 2–3 cm on the sides of ridges and cover with a thin layer of soil. Irrigate after 1 or 2 days after sowing depending on soil moisture. During rainy season, the seeds are sown 2–3 cm deep on ridges and in furrows during summer months. A seed rate of 10–15 kg/ha is required. Alternatively sowing by broadcast can also be done with 15–20 kg/ha of seeds.

Intercultural operations

25 kg N/ha should be applied as top dressing at the time of earthing up after one month of sowing. Keep the plots weed free with 2–3 manual weedings. Irrigate the crop as and when required.

Pest and Disease management

Diseases

Major diseases are powdery mildew, leaf blight, and bacterial blight

From onset of powdery mildew disease, foliar application of dinocap (0.1%) or wettable sulphur (0.3%) can effectively reduce the disease.

Spray chlorothalonil (0.2%) or mancozeb (0.25%) when leaf blight incidence is observed.

Seed treatment with streptocycline (0.03%) and sprays of copper oxychloride (0.3%) is found effective to control bacterial blight caused by *Xanthontonas campestris* pv. *cyarnopoidis.*

Insect pests

Major insects are aphids, leaf hopper and pod borer.

Ahids can be controlled by spraying acephate 1 g/l of water.

Leaf hopper can be controlled by spraying ekalux 2 ml/l of water.

Pod borer can be controlled by spraying carbaryl 2 g/l or rnonocrotophos 2 ml/l of water.

At least two rounds of plant protection sprayings should be done using botanical insecticides to prevent sucking and chewing pests.

Harvesting and yield

The green pods for vegetable purpose are harvested when they attain the marketable stage. Only tender and non-fibrous pods should be handpicked for market purpose. Generally first picking starts 50- 60 days after sowing. About 8–10 pickings can be done in a total duration of 100 days. Average yield is 50–60 q/ha under rainfed condition. Generally 100–120 q/ha of fresh pods can be obtained

under irrigated conditions. Some of the high yielding varieties may give a yield of 200 q/ha.

Seed production

As in French bean.

GREEN PEA

Fig. 12. Green pea

Green pea is a very popular winter season crop and is native of Europe and Western Asia. Pea probably originated in Southwestern Asia, possibly northwestern India, Pakistan or adjacent areas of former USSR and Afghanistan and thereafter spread to the temperate zones of Europe. Based on genetic diversity, four centers of origins, namely, Central Asia, the Near East, Abyssinia and the Mediterranean have been recognized. Pea was introduced into the Americas soon after Columbus and a winter type pea was introduced from Austria in 1922. Pea was taken to China in the first century. Peas were reported to be originally cultivated as a winter annual crop in the Mediterranean region.

Pea is a very common crop during winter throughout the plains of India. In India pea is grown in an area of 408,000 ha with a production of 3745,000 t and productivity of 9.2 tonne/ha. The major peas producing states are Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Orissa and Karnataka (NHB, 2011).

It is rich in protein, carbohydrates, vitamin A and C, calcium and phosphorus. It also contains a small quantity of iron. The green pod in certain varieties is edible and is usually cooked in various vegetable preparations in different regions of the country. It has a good market in the dehydrated and canned forms. 100 g of peas contains moisture 11 g, protein 22.5 g, fat 1.8 g, carbohydrates 62.1 g, calcium 64 mg, iron 4.8 mg, riboflavin 0.15 mg, thiamin 0.72 mg and niacin 2.4 mg.

Botany

Pea (*Pisum sativum* L.) is a self-pollinated crop and belongs to the family Leguminosae/Papilionaceae and the genus *Pisum*. The genus *Pisum* includes 6–7 species out of which only *Pisum sativum* (2n = 14) is cultivated. The plant is a short lived, herbaceous annual and climber. The cultivars may be dwarf, semi-dwarf or tall. The flowers are solitary, axillary or up to 3 flowers per raceme, bracts very small, calyx oblique, corolla white, pink or purple; stamens diadelphous, filaments broad, anthers uniform, style falcate, flattened, stigma minute terminal. Pods swollen or compressed, straight or curved on short stalk. Seeds are angular or globose, smooth or wrinkled. Pea is a self-pollinated crop. The fruit which is eaten is a 'pod' botanically. Garden peas are treated as *P. sativum*

ssp. *hortense* Asch. & Graebn.; field peas as *P. sativum* ssp. *arvense* (L.) Poir.; and edible podded peas as *P. sativum* ssp. *macrocarpon;* early dwarf pea as *P. sativum* var *humile*. Later, it was reported that pea comprises only two species, *viz*; *Pisum sativum* and *P. fulvum* Sibeth. & Smith.

The snow pea (*Pisum sativum* var. *saccharatum*) is a legume, more specifically a variety of pea eaten whole in its pod while still unripe. The name *mangetout* (French for "eat all") can apply both to snow peas and to snap peas. Snow peas, along with sugar snap peas and unlike field and garden peas, are notable for having edible pods that lack inedible fibre (in the form of "parchment", a fibrous layer found in the inner pod rich in lignin) in the pod walls. Snow peas have the thinner walls of the two edible pod variants.

Breeding

Breeding objectives of garden pea are high green pod yield, high shelling percentage, suitable for freezing, resistance/tolerance to diseases and pests. Breeding systems include pedigree method, backcross method, mutation breeding, bulk method, individual plant selection and single seed descent method. Micro propagation of peas is done by tissue culture using apical meristems of seedlings and through somatic embryogenesis (Arya, 2003).

Pea has been grown in India for several decades and is quite adapted to this part of the world. There are a good number of local strains and exotic varieties available. Most of the exotic varieties were introduced in India and used as commercial varieties and hence significant efforts were not made to breed varieties for various purposes. There has been an acute need for breeding varieties for high yield, better processing and cooking qualities and disease resistance. Some of the genetic information with regard to economic characters and male sterility have been reported. Rust and powdery mildew resistant varieties have been released. A high yielding rust resistant variety Arka Ajit has been released by IIHR, Bengaluru (Nath *et al.* 2002).

Improved cultivars

Disease resistant cultivars

Pusa Pragati: Developed by IARI, New Delhi. Early powdery mildew resistant variety. Average pod length 10 cm with 9 seeds per pod. Maturity 60–65 days. Yield 67 q/ha.

Arka Ajit: Developed by IIHR, Bengaluru. A mid season variety. Pods 8–9 cm long; seeds bold green, sweet, shelling percentage 55, resistant to both powdery mildew and rust. Duration 90 days and Yield 10 tonne/ha. It is recommended for U.P, Rajasthan and Karnataka.

Arka Sampoorna: Developed by IIHR, Bengaluru. The plants are bushy erect. Pods are flat, parchment less, crisp, sweet, resistant to powdery mildew and rust. Duration 80 days and yield 8 tonne/ha.

Arka Karthik: Developed by IIHR, Bengaluru. Plants bushy, erect and resistant to both powdery mildew and rust. Pods are long (11–12 cm) with 8–10 green, sweet seeds. Crop duration 90 days pod yield 11 tonne/ha.

Swarna Mukti: Released by ICAR-RCER, Patna. Recommended for cultivation in Jharkhand, Bihar, West Bengal and Odisha. Resistant to powdery mildew. Time of sowing: Sept–Oct. Yield: 200–250 q/ha.

Pant vegetable pea–5: This is an early maturing variety of vegetable pea developed by GBPUAT, Pantnagar. The plant is dwarf. The pods are long, well filled and slightly curved towards the tip. The seeds are green and wrinkled at maturity. This variety is resistant to the powdery mildew disease. The first green pod picking can be done within 60- 65 days and seed maturity is recorded in 100–110 days after sowing. It gives a green pod yield of 90–100 q/ha. The variety is suitable for cultivation in Kumaon hills and the plains of Uttarakhand.

PM-2: Plant height 50–60 cm. Fruit setting starts from 6^{th} node. Pods green with 6 seeds/pod and seeds wrinkled when dry. Escapes powdery mildew. Maturity 55–60 days. Yield 100–120 q/ha.

Insect pest resistant cultivars

Kashi Nandini: Developed by IIVR, Varanasi. This is the earliest variety in the seed chain of the country and grown in the northern plains (25^{th} October–25^{th} November). Plants erect (60 cm) pods 8–9cms long. Shelling quality 47–48%. Duration 55 days. Yield 110–120 q/ha. Tolerant to leaf minor and pod borer. Suitable for Punjab, Uttarakhand U.P, Bihar, Jammu and Kashmir, Karnataka, Tamil nadu and Kerala.

Early season cultivars

Arkel: Plant dwarf, 40–60 cm tall, pods dark green about 8 cm long, slightly curved and well filled. Grains very sweet and wrinkled when dry. Suitable for sowing in mid October. Maturity 55–60 days. Yield 100–125 q/ha.

Early badger: Early, dwarf, wrinkle seeded variety, pods pale green, 7.5 cm long pods. Suitable for early October sowing. Maturity 60–65 days. Yield 50–60 q/ha.

Meteor: Plant dwarf, 50–60 cm tall, round seeded variety suitable for early October sowing. Maturity 55–60 days. Yield 90–100 q/ha.

Jawahar Matar-4: Plant height 70 cm, green pods, stem and foliage. Pods well filled. Mature seeds wrinkled green. Maturity 65–70 days. Yield 60–70 q/ha.

Early December: Plants bushy, 70 cm tall with white flowers. Pods round to oval shaped, 5 cm long, 1 cm broad and five seeds per pod. Maturity 65–70 days. Yield 60–65 q/ha.

Kashi Uday: Developed by IIVR, Varanasi. Early maturing 60–65 days duration, yield 110 q/ha.

Kashi Mukti: Developed by IIVR, Varanasi. Early maturing 60–65 days duration, yield 110–120 q/ha.

Kashi Shakhi: Developed by IIVR, Varanasi. High yielding, medium maturing, sown in November in plains, shelling quality 48–49%. Yield 140–160 q/ha.

Swarna Tripti: This is a snow pea variety released by ICAR-RCER, Patna. Recommended for cultivation in Jharkhand, Bihar, West Bengal and Odisha. Time of sowing: September–October. Yield: 240–280 q/ha.

Mid and late season cultivars

Bonneville: Mid season, medium tall, double, light green podded, wrinkle seeded variety, 8 cm long pods with 7–8, green, sweet, and bold seeds/pod. Maturity 55–60 days. Yield 100–120 q/ha.

Lincoln: Mid season, plants medium long, double podded, pods about 9 cm long, dark green and curved at the top, 8–9 seeds per pod. Suitable for sowing up to 15th December. More suitable for hills. Maturity 90–95 days. Yield 110–130 q/ha.

Early giant: Plants tall and need staking. Pods 9–10 cm long, dark green, late maturing. Wrinkle seeded variety. Suitable for hills. Maturity 90–100 days. Yield 100–110 q/ha.

NP-29: Double podded, mid season, wrinkle seeded, plants medium tall with dark green foliage. Pods 7.5 cm long and 6–7 seeds per pod, very sweet. Suitable for dehydration. Maturity 100 days. Yield 100–120 q/ha.

VL-3: Average plant height 67 cm, light green foliage, and light green pod. Average pod length 6.8 cm with 5 seeds/pod. Resistant to powdery mildew. Maturity 105 days. Yield 100–110 q/ha.

Pant Uphar: Developed by GBPUAT, Pantnagar. Plant height 75–80 cm, relatively thin small leaflets, foliage light green, and length of pod 7–8 cm. Susceptible to powdery mildew. Maturity 75–80 days. Yield 95–100 q/ha.

Jawahar Matar-1: Mid season variety, plant height 82 cm, leaves normal shaped, green in colour. Pod straight with bead like outgrowth at the lower end. Average size of the pod is 8.8 cm × 1.4 cm, 8–9 seeds per/pod, and mature seeds green in colour and wrinkle. Maturity 85–90 days. Yield 100–110 q/ha.

Perfection new line: It is a heavy yielding mid season variety introduced from America. The plant is medium tall and the pod is about 8 cm long, dark green, sweet and well filled with wrinkled seeds. It is ready for first picking in about 80–85 days.

Climate and soil

Pea is a cool weather crop and grows best at the optimum mean monthly temperature of 10–20 °C. Blossoms and pods are susceptible to frost, whereas leaves and stems are relatively tolerant. Seed germinates better at the soil temperature of 10–20 °C. It does not grow well in hot weather. Since, it is a cold loving plant, sowing can be taken up only during *rabi* season. A well drained sandy loam soil is suitable for growing garden pea. Excess moisture in the root zone results in poor growth of roots and conducive for the attack of root rot and root wilt pathogens like *Rhizoctonia* and *Fusarium* species. The soil *p*H between 6.5–7.5 is optimum for its good growth.

Cultural requirements

Sowing time: Sowing during the second fortnight of October is ideal as the temperature around 15–25^0 C will be favourable during pod maturity. Mid season varieties can be sown from the beginning of October to the middle of November in the plains. The early varieties can be sown in August-September.

Land preparation and sowing: The field should be well prepared with 3–4

ploughings. Ridges and furrows are prepared at a spacing of 60 cm. Incorporate 25 tonne/ha of FYM. Apply 25 kg N, 75 kg P and 60 kg K/ha as basal dose in the shallow furrows opened along the side of the ridges and cover with soil. Irrigate the furrows 2 days before sowing. Seeds are dibbled at a spacing of 10 cm within the rows.

Seeds are sown at a spacing of 10 cm by dibbling in shallow furrows made on the side of the ridges. Seeds are sown about 2.5 cm deep. This is followed by covering with thin layer of soil. Then the furrows are irrigated lightly. The seed rate is 75 kg/ha.

Intercultural operations

As in other vegetables crops, pea also requires regular soil moisture but the frequency of irrigation is much less than other common vegetable crops. Usually the irrigation is given immediately after sowing in the light soils. In heavy soils, the sowing should be done when enough soil moisture is available. Frequent irrigation is always avoided but the pea plant must be provided with irrigation at the pod filling stage or when frost is at hand.

Hoeing should be done to keep down weeds and provide good aeration for proper development of the roots. Top dressing with 25 kg N/ha is done after 30 days of sowing and earthing up is done. In case of tall indeterminate varieties, it would be advisable to provide stakes to the plants to harvest better quality pods.

Pest and disease management

Diseases

Major diseases are root rot, rust and powdery mildew

Treat the seeds with carbedazim or captaf @ 2 g/kg seeds. Spray carbendazim (0.1%) or tricyclazole (0.06%) to control root rot caused by Rhizoctonia. Drenching infected plants with carbenclazim (0.1%) when root rot is observed.

Spray chlorothalonil (0.2%), for the management of rust disease

From onset of powdery mildew disease, foliar application of hexaconazole (0.05%) or dinocap (0.1%) can effectively reduce powdery mildew disease.

Insect pests

Major insects are stem fly, pod borer and aphids.

To control stem fly, spray dimethoate (2 m1/l) or quinalphos (2 ml/l) at 20 and 30 days after sowing.

For aphids spray acetarniprid (0.5 ml/l) or dimethoate (2 ml/l).

Spray cypermethrin 25 EC @ 0.5 m1/1 or indoxacarb 14,5 SC @ 0.5 ml/l once in 10 days to control borers.

Harvesting and yield

The green pods of early varieties are ready for harvest in 45–60 days while mid and late season varieties, which are generally indeterminate, take 70–100 days. As the pod attains marketing stage it turns dark to light green and the grains are well filled in the pods.

In the processing industry, the maturity of pea is tested with the help of 'tenderometer'. The high quality of pea is tested by its tenderness and high sugar

content. Usually 3–4 pickings of pods are made during the season, which is spread over 2–4 weeks at 7–10 days interval; mid and late season varieties require more number of pickings.

Peas grown for home use or for fresh market are picked by hand before the seeds are fully matured and still in the pod and are used for immediate consumption. In some cases, gardeners and commercial growers make 2 or 3 pickings, depending on maturity, while other growers make only one picking, in which the vines are pulled and all pods are removed.

Dry peas are harvested when the pods are completely dry and can be threshed directly in the field by a combine. For dry peas timely harvest is important for maintaining quality and is usually done when the seed moisture content is less than 13%. Both premature harvesting and harvesting too late reduce the quality of the dry pea crop. If the pea crop is over mature, harvesting early in the morning or during the evening when relative humidity is low will minimize shattering and seed breakage.

The early varieties produce 25–40 q/ha of edible pods, mid season varieties produce 65–75 q/ha and the late season varieties produce 85–115 q/ha. The shelling percentage is 40–45. Pea cannot be stored for more than 2–3 days under ordinary conditions, but it can be stored for about 2 weeks at 0°C and 85–90% relative humidity.

Seed production

Cultural practices for seed production are similar to that for vegetable production. The following aspects need to be taken care of:

Pea flowers are almost self-pollinated. Hence, the isolation distance for peas is relatively short and aims mainly to avoid mechanical mixtures. However, the isolation distance may be at least 20 m from one variety to another.

Land should be kept clean by weeding and mulching. Irrigation should be provided as and when needed. Abundant water supply during flowering should be ensured. Late irrigation during warm weather should be avoided which may cause sun-scalding of plants as also plants may tend to lodge and some rotting of vines may occur if the soil is kept too wet. Careful roguing at flowering and after pod formation need to be done. Off-types and plants affected by blight and pea mosaic must be removed as soon as observed. The off-type and diseased plants affected by pea mosaic, foot-rot and blight should be rogued out from the seed field.

Maturity of seed crops take about 130–140 days. To test the maturity a common practice is to squeeze the seed between fingers. If the cotyledons break away from each other and free moisture is not visible, the crop may be considered mature enough for harvest. Vines along with the pods are harvested from the field and dried in the threshing floor under sunshine. Threshing is done by beating with stick when sufficiently dry. Care should be taken during threshing so that the seed coats are not injured. Threshed seeds are cleaned by winnowing, dried to reduce seed moisture content to 12% for temporary storage. For longer storage pea seed should be stored in sealed containers at 10% moisture content and in air cooled rooms. A seed yield of 1,200–1,500 kg/ha can be obtained.

VEGETABLE SOYBEAN

The Soybean is a native of the Far East. It has been an important food crop in China. Manchuria and Korea long before the dawn of human history. It was first referred to in a Chinese book written by Emperor Shennung of China as early as 2838 BC. It was given very great importance in China so much so that the Emperor of the country to sow it every year with great pomp. It is now very popular crop of the world over and is widely cultivated in the United States, Europe, South Africa, Egypt, Russia, Australia and other countries. In recent years several countries like Brazil, Mexico, Rumania, Paraguay and Argentina have substantially increased their Soybean production. India too has joined the Soybean race in its expansion programmer and there is growing awareness among the consumers in the country of the potential uses of Soybean.

The name Soy has its origin in the Chinese word shu and sou. The Indian name for soybean is *Soyabean.* The Aryans of Central Asia considered soya along with honey as sacred food to be offered to the departed. The ancient yogis of the indus valley civilization supplemented their meatless diet with this bean to ward off deficiency of good quality protein.

Soybean was known in India since a long time in the form of a marginal and traditional food plant. However, its feasibility as a crop was demonstrated through trials and experiments in the early 1900s and more systematic and vigorously in 1960s and onwards when a major initiative was taken through collaboration between USA and India. In the mid 1970s, soybean became a precious commodity and since then its area and production have been on the rise. The present annual production of grain soybean in India is about 6 million tonne with an average yield of one tonne/ha.

Vegetable soybean, a leguminous vegetable crop is similar to grain soybean except that it is harvested when the pods are still green and full. The seeds of vegetable soybean are larger (> 30 g/100 seeds dry weight), sweeter and more tender than grain soybean. 'Edamame' is a large seeded type of soybean that is eaten as a green vegetable.

Vegetable soybean is popular in Japan, Korea, China and Taiwan, and consumption is increasing very rapidly. The green-shelled beans can be cooked to make a tasty and nutritious meal or snack. Grain soybean is already widely cultivated in many countries of the tropics and subtropics, so the production of vegetable soybean can be readily adopted. The cultivation practices for vegetable soybean and grain soybean are similar except that vegetable soybean is harvested when the pods are green and full.

The seeds of vegetable soybean are commonly larger, sweeter and more tender than grain soybean. Such green seeds are commonly used in most countries. Even grain soybeans at green pod stage can be used as a vegetable. Vegetable soybean has excellent potential for enriching the human diet. It is a rich source of vitamin A and a good source of carbohydrate, protein and iron. It is more nutritious than vegetable green peas. In addition to domestic consumption, vegetable soybean also has export potential.

The soybean is esteemed for its high food value. It is a valuable source of

protein, vitamins, minerals and other food ingredients. It also contains vitamin B complex, biotin, folic acid, pantothenic acid, pyridoxine and vitamin E (Lal *et al.* 2003)

Botany

Soybean (Glycine *max* L.) belongs to the family Leguminosae. It is one of the most nutritious foods. It is perhaps one of the earliest crops cultivated by man and is one of the most important sources of oil and protein. The soybean is an annual plant which grows up to 150 cm in height. It has hairy, twining or climbing stems, alternate leaves and hairy, grey, brown or black, pods, borne in clusters on short stalks. Seeds are more or less round, with yellow, green, brown or black color.

Improved cultivars

Hara Soy (Himso-1563): This variety is released by HPKVV, Palampur. The culinary purpose variety. It is the first variety that has been released. The green pods of this variety can be used like green peas and also the dried beans as a pulse like dry peas. It has 100–120 days crop maturity period. It has green coloured seeds, easy to cook, attractive to look at and remains green even after cooking. In addition, it is sweet in taste and has negligible beany flavour. It has 43.0% protein and 19.0 per cent oil. It gives a fresh pod yield of about 50 q/ha and 150 q/ha green fodder. Grain yield is about 26 q/ha.

Swarna Vasundhara: Released by ICAR-RCER, Patna. Recommended for cultivation in Jharkhand, Bihar, West Bengal and Odisha. Time of sowing: June–July. Yield: 140–180 q/ha.

Varieties like PK-472, JS-335 and JS–71-05 are also preferred for consumption at green pod stage.

Climate and soil

The best planting date of vegetable soybean is dependent upon temperature and day length. The optimum temperature range of soybean cultivation is 20–30ºC with short day length (14 hours or less). However, planting should be avoided at cooler temperatures during winter. Loam soil with *p*H of 6.0–6.5 is suitable for its cultivation, but the field should be well drained.

Cultural requirements

Land tillage makes the soil friable for good germination, increases soil porosity and aeration for healthy plant growth, and kills weeds that compete with the crop for nutrients, moisture and light. Plow and rototill the field. To get a good harvest and maintain soil nutrient status of consistent productivity, a fertilizer mix containing N, P and K at the rate of 20, 60 and 80 kg/ha respectively, is applied by broadcast as a basal dose. The fertilizer is incorporated into the soil with final harrowing and leveling of the field.

The soil should not be too dry at the time of seedbed preparation. Irrigate the field 3–4 days prior to sowing to ensure sufficient moisture in the soil for good germination. Prepare 20 cm high raised beds spaced 1 m apart from center of one bed to the centre of the next bed. Spacing between rows is 45 cm and between

plants 5–10 cm depending upon seed size and season. Two to three seeds are sown in each hill. However, spacing between rows varies with variety and season.

A seed rate of 60–80 kg/ha is required to obtain a population of 400,000 plants/ha. Usually *Rhizobium* inoculation is not required in fields where legumes are cultivated. But newly opened lands need *Rhizobium* bacteria inoculations at 10 g/kg of seeds. This inoculation will promote nodule formation and nitrogen fixation by the plant roots. The seed is also treated with fungicides such as captan or thiram for protection against soil borne fungal diseases. Then the seeds can be dibbled by hand.

Intercultural operations

Keep the plot weed free. Maintaining proper soil moisture throughout the growing season is important for good quality pods. Usually, first irrigation is needed within a week after sowing. Irrigation is done in furrows. Depending upon weather and soil moisture conditions, the irrigation is continued at 6–7 day intervals until the pods are well developed. Irrigating the crop is essential at critical periods such as flowering and pod filling stages. The first side dressing is done at the rate of 20 kg N and 25 kg K/ha along the plant rows at flowering, for higher pod set. A second application of 20 kg N/ha is done at the beginning of the pod filling stage to improve seed size.

Pest and disease management

Diseases

Rust: This disease may be a serious problem, especially for seed production, causing up to 100% yield loss. Tan, dark brown or reddish brown lesions occur on leaves of affected plants. No commercial varieties are resistant to rust. Fungicides such as mancozeb or triadimefon @ 2 g/l of water may be sprayed at 10-day intervals to control rust.

Downy mildew: This disease occurs during spring and autumn seasons but it does not generally cause yield reduction. The symptoms are pale green to light yellow spots on the surface of the leaf. These spots enlarge into pale to bright yellow lesions. The underside of the leaf shows white powdery spores. To control downy mildew, plant resistant cultivars. For susceptible cultivars, spray fungicides such as mancozeb @ 2 g/l of water.

Bacterial pustule: This disease can cause yield losses of up to 40%. Early symptoms are small pale green lesions that become water-soaked with bacterial ooze that dries to become white crust on upper/lower leaf surfaces. The best way to control this disease is by planting resistant varieties.

Insect pests

Bean fly (*Ophiomyia phaseoli*, *O. centrosematis*, *Melanagromyza sojae*, and other species): This is a serious pest of soybean. Bean fly larvae feed inside the plant stem and their initial damage cannot be recognized easily. Bean fly populations are higher in the cool autumn compared to long dry-weather conditions in spring. Soybean must be protected against bean fly. For the autumn crop monocrotophos, or dimethoate is sprayed @ 2 ml/l of water.

Coreid and stink bugs: They commonly occur late in spring and summer season crops. If you notice high populations (i.e. 3–4 insects per meter row) uniformly over the entire field in early pod filling stage, spray insecticides such as fenvalerate @ 2 ml/l of water.

Defoliators: They feed on leaves. Minor damage does not require insecticide application, but when the attack is severe, they can be controlled by the insecticides used for stink bug control. Stop spraying chemicals at least 10 days prior to harvest. Overuse of insecticides or fungicides is hazardous for human and animal health.

Harvesting and yield

Harvesting is done when 80% of the pods have reached physiological maturity stage. It may take 65–75 days after germination for vegetable soybeans to be ready for harvest depending upon variety, temperature and weather conditions. The pods are still green. Vegetable soybeans are specialty beans harvested at about 80% maturity in green-yellow pod and used green. They normally have large pods with large size seeds (200–250 mg per seed or more) and sweet taste. At this stage, the seeds are still green, large and soft. Fresh soybean pods are harvested, cleaned and cooked with salt for 10–15 minutes until tender and then served. The fresh beans are often shelled, cooked like other beans and served as a seasonal vegetable. Shelled beans can also be cooked along with rice to add delicate taste and complementary protein to the cooked rice. The steamed fresh bean has the highest net protein utilization (NPU) value among all soy food products. Soy sprouts are also eaten as vegetable. The pods are stripped from the plants by hand. Grading is important for export of good quality vegetable soybeans. The diseases and insect damaged pods and pods with spots and blemishes are sorted out. The good marketable yields are 70–100 q/ha of pods.

Seed production

As in French bean

WINGED BEAN

The centre of origin of winged bean is still uncertain. It is reported to be of African origin, perhaps Madagascar. Papua New Guinea is the greatest centre of diversity though no other wild or cultivated species of this genus occurs in that country. Kerala, Karnataka and part of Tamil Nadu region seems to be the secondary centre of origin of winged bean. It is also known as Goa bean, ridged bean, four angled bean. The winged bean has been cultivated for generations in humid tropics of South and Southeast Asia, particularly India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Vietnam, Laos, Kampuchea, Philippines, Indonesia and Papua New Guinea.

It is grown as a field crop in Papua New Guinea, Burma and Thailand. In India it is grown at least in eight states including Asom, Manipur, Mizoram, Kerala, Tamil Nadu and Karnataka by the tribal people as a backyard crop. The results of trials encourage hoping for its successful cultivation in north Indian plains also. The winged bean is used as a green vegetable of half grown pods. The leaves, flowers, seeds, stem and tuberous roots are also eaten in a variety of preparations.

It also forms an excellent source of dietary protein and oil. It has remarkably high protein content in most of the edible portions and is similar to soybean. Its dry seeds contain 30–40% protein and 15–20 per cent oil. The green tender pods contain 2–4% protein on fresh weight basis and 15% on dry weight basis. Its tubers also contain 11–15% protein which is 5 to 10 times more than in potato, sweet potato, cassava etc. In spite of reported presence of trypsin inhibitor in winged bean, it contains an antioxidant tocopheral that enhances utilization of vitamin A in the human body. No adverse effects have been reported so far.

Botany

Winged bean (*Psophocarpus teragonolobus* (L.) DC.) belongs to the family Leguminosae. The winged bean is a twining perennial herb grown as annual. All the cultivars are indeterminate in growth and have the pods with longitudinal wings. It is also known as Goa bean, Manila bean and four angled bean. *Psophocarpus* has about 9 species but only *tetragonolobus* is the common one. Though it is normally a self-pollinated crop, the cross-pollination occurs to the extent of 7.6%. It has chromosome number 2n=18.The flowering in winged bean occurs between 50 to 90 days after planting and the pods mature in 3-5 months.

Breeding

A very fast approach has been made to study various genetic and plant breeding facets of winged bean at international level. In India it is dealt with under a separate All India Coordinated project on under utilized crops. Active research is being coordinated at the International Research Centre in Sri Lanka. In India, useful information has been gathered by IIHR, Bengaluru; NBPGR, New Delhi; NBRI, Lucknow and at two international symposia held during the past 5–6 years in the Philippines and Sri Lanka. Some researchers have contributed greatly by publishing monograph and review articles. In India, a few selections have been reported such as No 21, No 60 and No 71 at the IIHR, Bengaluru and WBC-2 in Meghalaya and JCV 44 in West Bengal. The winged bean exhibits a wide genetic variation in size, shape, and colour of pods, leaves, flowers and seeds.

Improved cultivars

No improved variety has been released in India though a selection was recommended from NBRI, Lucknow, for cultivation. Certain varieties like; Bogor', Ribbon', Butterfly', 'Maripusa', 'Lunita', 'Always', 'Alipasto', 'Dual', 'Chimbu' and 'Tinge' are available in markets of Puerto Rico and South East Asia which can be tried in India also.

Climate and soil

It can withstand high temperature but not the frost and water logging. Except alkaline and sodic soils, it can be grown on a range of soil types from sandy to clay with soil *p*H from 4.3–8.5.

Cultural requirements

The sowing is generally done from the end of July up to October at a spacing

of about 1 m between rows and 25–70 cm between plants at a depth of 2–3 cm. Seeds germinate in 5–15 days after sowing. Plants flower during short days between 18 and 32 °C.

The varieties differ in sensitivity to day-length. The flowering can continue for about 8 months, if green pods are removed periodically. While the rain destroys most other beans, winged beans flourish in rain. If rains are not frequent, irrigation will be necessary. Irrigation is required weekly until the plants are large and have roots deep enough to resist short droughts.

To trail the branches it needs a bower or trellis. It grows vigorously and flowering starts within three months. It is an excellent nutritious and delicious vegetable. Yield is poor without staking.

A fertilizer dose of 40 kg N, 100 kg P and 40 kg K/ha is applied. 20 kg N, 100 kg P and 40 kg K/ha is applied as basal dose at the time of sowing. The remaining 20 kg N/ha is applied as top dressing 30 days after sowing. The weeds are required to be controlled in the first month of its establishment after sowing.

Pest and disease management

There are no very serious pests on winged bean except nematodes and some viruses. Sandy soils should be avoided from cultivation to escape from nematodes.

Harvesting and yield

The winged bean has prolific pod bearing capacity (up to 75 pods per vine). A yield of 24–40 q/ha of seeds or 250–350 q/ha of green pods and 80–110 q/ha of tubers can be obtained.

LIMA BEAN

Although Lima bean or butter bean has been cultivated in Peru for more than 7,000 years, historians are unsure whether they originated there or in Guatemala. Soon after Columbus' discovery of America, Spanish explorers noticed different varieties of lima beans growing throughout the South America, Central America and the Caribbean. They introduced them to Europe and Asia, while the Portuguese explorers introduced lima beans into Africa. Since lima beans can withstand humid tropical weather better than most beans, they have become an important crop in areas of Africa and Asia. Lima beans were introduced into the United States in the 19th century with the majority of domestic commercial production centered in California.

Sometimes called "butter beans" because of their starchy yet buttery texture, lima beans have a delicate flavor that complements a wide variety of dishes. Although fresh lima beans are often difficult to find, they are worth looking for in the summer and fall when they are in season. Dried and canned lima beans are available throughout the year. As Lima beans are most often associated with succotash, a traditional Native American dish that combines this delicious bean with corn, many people think that they are native to the United States. Yet, one of lima beans' proposed places of origin, the place where the early European explorers were thought to have first discovered them, is actually reflected in its name "Lima," the capital of the South American country of Peru.

Botany

Lima bean or butter bean (*Phaseolus lunatus*) belongs to the family Leguminosae. The pod of the lima bean is flat, oblong and slightly curved, averaging about 7.5 cm in length. Within the pod are the two to four flat kidney-shaped seeds that we call lima beans. The seeds are generally cream or green in color, although certain varieties feature colors such as white, red, purple, brown, or black.

Both bush and pole (vine) varieties exist, the latter ranges from one to four metres in height. The bush varieties mature earlier than the pole varieties. The pods are up to 15 cm long. The mature seeds are 1–3 cm long and oval to kidney shaped. In most varieties the seeds are quite flat, but in the "potato" varieties the shape approaches spherical. White seeds are common, but black, red, orange and variously mottled seeds are also known. The immature seeds are uniformly green. Lima beans typically yield 2,900–5,000 kg of seeds. In the UK, "butter beans" refers to either dried beans which can be purchased to rehydrate, or the canned variety which are ready to use. In culinary use, lima beans and butter beans are distinctly different, the former being large and yellow, the latter small and green. In areas where both are considered to be lima beans, the green variety may be labelled as "baby" (and less commonly "junior") limas.

Improved cultivars

While there are many varieties of lima beans, the ones that are most popular in the U.S. are the Ford hook, commonly known as the butter bean, and the baby lima bean. The pod of the lima bean is flat, oblong and slightly curved, averaging about three inches in length. Within the pod reside two to four flat kidney-shaped seeds that are what we generally refer to as lima beans. The seeds are generally cream or green in color, although certain varieties feature colors such as white, red, purple, brown or black. Lima beans feature a starchy, potato-like taste and a grainy, yet slightly buttery, texture. Lima beans, or butter beans, come in both bush or pole varieties.

KKL 1: This variety released by TNAU, Coimbatore, is a pole type growing up to 2.5 m and bears pods in clusters. The pods are 11.6 cm long, beans are 5–6 in number per pod. The pods are green when immature, turning creamy yellow with brownish purple streaks on the surface at maturity. The seeds are bold, globular, snow white in colour and with excellent cooking quality. The variety is suited for hilly regions of Tamil Nadu from an altitude of 1,200–2,200 m above MSL. The crop will be ready for first harvest from 100 days after sowing. The harvest will continue upto 140 days. It yields 35 q/ha of ripe pods in 3–4 pickings.

Climate and soil

Both the bush and pole types of lima beans have larger and more spreading vines than their snap bean counter parts. Lima beans do best in areas where summers are long and rather warm. To germinate properly, lima beans need warmer soil than snap beans. They also need higher temperatures and a longer growing season for a good crop. Lima bean seeds require soil temperatures of at least 20°C for a minimum of five days to germinate.

Cultural requirements

The cultural operations are the same as those for french beans. Limas are panted like snap beans except they need more space. Prepare ridges and furrows at 45 cm apart. Plant to plant spacing of 10–12 cm within a row should be maintained.

Seeds of pole beans should be planted 10–15 cm apart in rows 75–90 cm apart. Or, plant them in inverted hills, 5–6 seeds to a hill, with 75 cm of space around each hill. For pole bean varieties, set the trellis at the time of planting to avoid disturbing the roots. The lima bean seed sometimes has trouble pushing through the soil, although this should not happen if the soil is well worked. Cover seeds 2.5 cm deep in clay soils, 4 cm in sandy soils.

Intercultural operations

To avoid the spread of diseases from plant to plant, cultivate shallowly and only when the foliage is dry. Water frequently by soaking the soil instead of sprinkling. Moist foliage invites bacterial disease in humid areas. High nitrogen fertilizers and heavy application of compost will encourage more foliage growth than vegetable production.

Harvesting and yield

With this type of bean, the maturing seed is eaten, not the entire pod. Pick pods before the seeds have become tough. Ripe pods usually pop open when you press them along the seams. Therefore, picking lima beans should begin once the pods are well filled and beans are still tender. Picking should be done regularly for continual yield.

BROAD BEAN

Broad bean, also known as fava bean, field bean, bell bean, tic bean, is native to North Africa and Southwest Asia, and is extensively cultivated elsewhere. Broad beans have a long tradition of cultivation in old world agriculture, being among the most ancient plants in cultivation and also among the easiest to grow. In much of the anglophone world, the name broad bean is used for the large seeded cultivars grown for human food, while horse bean and field bean refer to cultivars with smaller, harder seeds (more like the wild species) used for animal feed, though their stronger flavour is preferred in some human food recipes.

The term fava bean (from the Italian *fava*, meaning "broad bean") is usually used in English speaking countries such as the US, however the term broad bean is the most common name in the UK. Broad beans are eaten while still young and tender. The young leaves of the plant can also be eaten either raw or cooked like spinach. The beans can be fried, causing the skin to split open, and then salted and/or spiced to produce a savory crunchy snack.

Botany

Broad bean (*Vicia faba* L.) is a species of bean belonging to the family Leguminosae (Fabaceae). It is a rigid, erect plant 0.5–1.8 m tall, with stout stems with a square cross section. The leaves are 10–25 cm long, pinnate with 2–7

leaflets, and of a distinct glaucous grey green color; unlike most other vetches, the leaves do not have tendrils for climbing over other vegetation. The flowers are 1–2.5 cm long, with five petals, the standard petal white, the wing petals white with a black spot (true black, not deep purple or blue as is the case in many "black" colourings), and the keel petals white. Crimson flowered broad beans also exist, which were recently saved from extinction. The fruit is a broad leathery pod, green maturing to blackish-brown, with a densely downy surface; in the wild species, the pods are 5–10 cm long and 1 cm diameter, but many modern cultivars developed for food use have pods 15–25 cm long and 2–3 cm thick. Each pod contains 3–8 seeds; round to oval and 5–10 mm diameter in the wild plant, usually flattened and up to 20–25 mm long, 15 mm broad and 5–10 mm thick in food cultivars.

Improved cultivars

Pusa Udit: This is released by IARI, New Delhi. Pods are extra long, flattish and light green. This is a dual purpose broad bean variety. The variety is suitable for packaging and transport. The variety gave 88.52% higher yield than the earlier released variety Pusa Sumeet.

The other varieties are Pusa Sumeet, Large Poded, and Small Poded.

Climate and soil

The broad bean has high hardiness cvs. This means it can with-stand rough climates, and in this case, cold ones. Unlike most legumes, the broad bean can be grown in soils with high salinity. However, it does prefer to grow in rich loams.

Cultural requirements

Broad beans are easy to grow and are great for the novice and expert gardener alike. Broad beans require well manured soil. The soil should be well drained. Water well if weather is dry and keep weed free. The earlier broad beans are sown the less likely they are to become infested with black-fly. Broad beans can be planted as soon as the soil can be worked. Broad beans prefer a moist, cool soil for growing. Sow 3–5 cm deep and 15 cm apart in rows 60–90 cm apart.

Intercultural operations

Broad beans are light feeders, requiring a well drained soil with a *p*H of 6.0–6.8. A one time application of compost or well rotted manure will be sufficient. Pinching back the top of the broad bean plant when the first pods begin to form will provide a higher and more uniform yield. Large plants require support; hill soil up around the base of the broad beans as it grows.

Harvesting and yield

The plants are 60–100 cm tall. They bear numerous initially upright pods in the axils of the leaves along the stem. At market maturity, the green pods are slightly rounded about 2 cm in width and 15 cm or more in length. Each cluster contains 5–6 fleshy beans. Pick beans when pods appear plump.

SWORD BEAN

Canavalia gliadata is known as "sword bean", due to the seed pod's resemblence to the blade of a sword and its Malay name is in fact "kacang parang". It originated from tropical Asia and Africa. The sword bean has a close relative, the jack bean, *Canavalia ensiformis*, which originated from South and Central America. Both species are easily confused with one another. Both legumes are grown as a green manure crop or cover crop and used as a fodder, which is not very palatable to livestock.

The young pods of both beans are actually eaten as a vegetable in tropical Asia and pickled in Japan. The mature seeds are a good source of protein but should never be eaten raw as they contain a toxic amino acid, canavanine, which is an antimetabolite of arginine. Canavanine has been found to be cytotoxic to human pancreatic cancer cells. Lectins - concanavalin A and B found in the mature seed can inhibit the absorption of nutrients by the gut. Overnight soaking of the seeds and boiling them in excess water will significantly reduce the canavanine content in them. Heating will also denature the antinutritive lectins. The soaking and cooking water should be discarded. The seeds are also a source of urease, which is used in molecular biology.

In Madagascar the young green fruits and immature seeds of sword bean are used as a cooked vegetable. Sword bean is eaten in Tanzania, where the Swahili expression 'eating sword bean' means 'being happy'. Use of the fruits and immature seeds is also reported from Sri Lanka, India, Indonesia, China, Korea and Japan. Sword bean is further planted as a forage and cover crop.

The ripe seeds can be eaten after cooking, but only after removing the seed-coat and several changes of water. The seed is used as feed for cattle and chicken, but if eaten in considerable quantity dry seeds may cause poisoning. Sword bean is grown as an ornamental climber on fences and houses. Urease is extracted from the seed; it is used in clinical laboratories for the *in vitro* determination of urea in human blood. In Korea it is used in the treatment of vomiting, abdominal dropsy, kidney related lumbago, asthma, obesity, stomach ache, dysentery, coughs, headache, intercostal neuralgia, epilepsy, schizophrenia, inflammatory diseases and swellings. In Japan it is effective in treating ozena, haemorrhoids, pyorrhea, otitis media, boils and cancers, all kinds of inflammatory diseases and atopic dermatitis. In Korea soap is marketed based on extracts of sword bean; it is used for the treatment of athlete's foot and acne.

Botany

Sword bean (*Canavalia gladiata* (Jacq.) DC.) and jack bean (*Canavalia ensiformis* (L.) GC.) belong to the family Leguminosae (Leguminosae - Papilionoideae, Fabaceae). They are perennial trailing or climbing herbs up to 10 m long, often grown as an annual; root system deep. Leaves alternate, pinnately 3-foliolate; stipules small, deciduous; petiole 5–17 cm long; leaflets with 4–7 mm long stalks, ovate, 7.5–20 cm × 5–14 cm, apex acuminate, shortly pubescent on both sides. Inflorescence an axillary raceme 7–12 cm long; peduncle 4–20 cm long. Flowers bisexual, papilionaceous, often resupinate; calyx up to 1.5 cm long,

2-lipped with a large 2-fid upper lip and a much smaller 3-fid lower lip; corolla white, standard c. 3.5 cm long; stamens 10, all joined; ovary superior, style slender, curved, stigma small. Fruit a linear-oblong pod, slightly compressed, sometimes curved, 20–40(–60) cm × 3.5–5 cm, widest near the apex, 8–16-seeded, spirally dehiscent; each valve with ventral rib and extra rib spaced c. 4 mm. Seeds 2–3.5 cm × 1.5–2 cm, red or red-brown, rarely black, pink or white; hilum 1.5–2.0 cm long. Hilum is the scar on a seed, such as a bean, indicating the point of attachment to the funiculus. Seedling with epigeal germination; first 2 leaves simple, opposite, with stipules connate.

Mature plants of both species are difficult to distinguish from one another. Pod sizes of both species have very slight differences in terms of length and width. Perhaps the only feature that can be used to tell the two species apart is the difference in the appearance of the seeds. The seed of the sword bean is usually red or pink, and is rarely white. The seed of the jack bean is smaller and ivory white in colour. Its hilum less than half as long as the seed of the sword bean. The hilum refers to the small scar where the seed was attached to the parent plant, in this case, part of the fruit.

Breeding

Sword bean is not known from the wild and must have undergone selection during centuries. Selection has favoured increased pod and seed size but has not resulted in a reduction in biochemical toxins. This would be consistent with selection for use as fodder or as a green fruit vegetable rather than as a pulse crop. Breeding is difficult as the flowers are very sensitive to damage during emasculation and emasculated flowers usually abscise; therefore bud pollination is recommended. In South-East Asia sword bean cultivars have been developed with reduced toxicity. Hybrids of *Canavalia gladiata* with both *Canavalia africana* and *Canavalia ensiformis* have occurred from natural crosses. Breeding programmes should use this wide base of germplasm.

Improved cultivars

Thar Mahi: This sword bean variety is released for arid region by the Central Institute for Arid Horticulture (CIAH), Bikaner, Rajasthan. First fruit harvest takes place 90–95 days after sowing. Average pod yield is 1.7 kg/plant giving an yield of 56 q/ha.

Climate and soil

Sword bean requires temperatures of 20–30°C and is cultivated from sea-level up to 1,000 m altitude. It is tolerant of drought once established and also tolerant of water-logging, shade and salinity, making it one of the most hardy tropical legumes. It prefers an evenly distributed annual rainfall of 900–1,500 mm. It grows well even on nutrient depleted soils

Cultural requirements

Both sword bean and jack beans are relatively easy to grow. The seeds germinate readily within a week. Because the vines are rampant and sprawling, a large trellis

needs to be erected for them to climb on. Both legumes are not fussy about soil type and fertility and are relatively drought resistant. Give the plants plenty of room to grow - plants in row are to be spaced 60 cm apart and 90 cm between two adjacent rows. The vines are best grown under full sun but are tolerant of some shade. Provide a good base of a balanced fertilizer before sowing of seeds and feed with a flowering and fruiting fertilizer only occasionally during growth. Overfeeding with nitrogen may depress the yield of pods. Most importantly, these plants are seldom bothered by pests and diseases.

Given the right conditions, the seedling will turn into a large, vigorous climber in about two months. From the third month onwards, it should produce arching sprays of red or white coloured flowers. These will form into long green and flat bean pods. When allowed to mature and dry on the vine, the pod, when split, will yield the familiar looking pink beans.

Sword bean is usually grown by small-holder farmers near houses and allowed to climb on walls, fences and trees. Seeds are sown at a depth of 5–7.5 cm. As a field crop, it is usually sown at a spacing of 75–90 cm between rows and 45–60 cm within the row, at a seed rate of 25–40 kg/ha. Sword bean seed germinates readily and the plant is relatively fast growing. Flowers are pollinated by insects and 20% or more cross-pollination occurs. To avoid a buildup of pests and diseases it is recommended that sword bean be treated as an annual crop or retained at most for two years.

Harvesting and yield

Young sword bean fruits can be harvested from 3–4 months after sowing when they are 10–15 cm long, before they swell and become fibrous and tough. Mature seed can be harvested after 5–10 months. As the fruits shatter their seeds when ripe, harvesting should be done timely. Yields of green fruits can be upto 40 q/ha. Forage yields of upto 600 q/ha have been reported. Seed yields of up to 54 q/ha are possible, but a seed yield of 15 q/ha is more common.

SCARLET RUNNER BEAN

Scarlet runner bean is native of Mexico and Central America. It is also known as red flower vegetable bean. The runner bean is commonly cultivated in many parts of the world for its edible seeds and immature seedpods. The edible parts are the flowers, leaves, immature pods, roots, seeds. Immature seed pods are used raw or cooked. They have a pleasant mild flavour and are widely used as a vegetable in many areas of the world. They can be added to salads, cooked as a vegetable or added to soups, stews *etc.* The immature seed is used like shelled beans as a vegetable. Flowers are used raw; a bean like taste. Young leaves are cooked and used as a potherb. Root are used after cooking; it is rich in starch.

The protein rich mature seeds can be dried and stored for future use. They need to be thoroughly cooked before being eaten in order to destroy a toxic principle. They are soaked for 12 hours prior to use and are eaten boiled or added to soups *etc.* The seed can also be ground into a powder and added to cereal flours for making protein enriched bread *etc.*

Botany

Scarlet runner bean (*Phaseolus coccineus* L.) belongs to the family Leguminosae and the genus *Phaseolus.* In warm climates, a perennial but normally grown as an annual, a twiner to 4.5 m; roots tuberous reputed to be poisonous; leaves 3-lobed large; flowers showy red, white or variegated, racemes longer than leaves; pods to 25 cm long; seeds large variously coloured; germination hypogeal. The flowers are hermaphrodite (have both male and female organs) and are pollinated by bees. The plant is self-fertile. It can fix nitrogen.

Climate and soil

Requires a warm sheltered sunny position in a rich well-drained soil with plenty of moisture in the growing season. Dislikes heavy, wet or acid soils. Prefers a *p*H in the range 6–7. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils and requires well drained soil. The plant prefers neutral and basic (alkaline) soils. It cannot grow in the shade. It requires moist soil.

Improved cultivars

There are many named varieties. Most varieties are climbing plants but some dwarf forms have been developed.

Cultural requirements

Plants are perennials but are often grown as annuals. Presoak the seeds for 12 hours in warm water and sow in the field. Germination should take place within 10 days. Plants flower under long day conditions. This species has a symbiotic relationship with certain soil bacteria; these bacteria form nodules on the roots and fix atmospheric nitrogen. Some of this nitrogen is utilized by the growing plant but some can also be used by other plants growing nearby.

Harvesting

When grown for their edible pods, the immature pods should be harvested regularly in order to promote extra flower production and therefore higher yields.

VELVET BEAN

Velvet bean is native of Southern China and Eastern India. It is now widely distributed in the tropics. The common names for velvet bean are Mauritius bean, itchy bean, buffalo bean, bengal bean, and mucuna.

Velvet bean is an indigenous medicinal climber belonging to family Fabaceae, commonly known as kewanch, and cow itch. The seeds of kewanch are a source of L-dopa (L-3, 4-dihydroxyphenylalanine), used in the treatment of parkinson's disease. In Ayurveda, it is regarded as nervine tonic, aphrodisiac and diuretic. Besides this, Mucuna is a green manure, cover crop and also used as food and fodder. The immature pods and leaves are occasionally boiled and eaten as a vegetable.

Botany

Velvet bean (Mucuna pruriens (L.)DC. var. *utilis*; syn. *Mucuna deeringiana*

Small; *Stizolobium deeringianum* Bort.) belongs to the family Fabaceae (*alts.* Leguminosae) and the genus *Mucuna.* Vigorous annual (sometimes biannual), twining herb, stems extending up to 18 m in length. Large trifoliate leaves, lateral leaflets conspicuously asymmetrical, 7–15 cm long, 5–12 cm wide, terminal leaflet symmetrical, somewhat smaller. Inflorescence an axillary raceme, up to 32 cm long, many-flowered, flowers pale purple or white. Pods oblong, 4–13 cm long, 1–2 cm wide, usually more or less S-shaped, finely pubescent with white to light brown hairs. In wild forms (var. pruriens rather than var. utilis), hairs contain skin irritation causing mucunain; cultivated varietes are non-stinging. Pods contain up to 7 oblong-ellipsoid seeds, 1–1.9 cm long, 0.8–1.3 cm wide, 4–6.5 mm thick and of variable colour (black, maroon, creamy, white, grey, beige, brown, and mottled), hilum surrounded by a prominent, cream coloured aril. 100-seed weight ranges from 55–85 g.

Improved cultivars

Arka Dhanvantri: Identified for release by IIHR, Bengaluru. It is identified for high yield, high L-dopa content and early maturity. This variety lacks itchy trichomes on pods and are suitable for commercial cultivation.

Arka Aswini: Identified for release by IIHR, Bengaluru. It is identified for high yield, high L-dopa content and early maturity. This variety lacks itchy trichomes on pods and are suitable for commercial cultivation.

Climate and soil

It is susceptible to frost but, because of its short life-span, can be grown in the sub-tropics. It performs best at altitudes from 0–1,600 m, but can be grown up to 2,100 m MSL. For grain production, altitudes of 1,200–1,500 m asl are best. It prefers hot, humid climates with annual rainfall of 1,000–2,500 mm, but will grow in environments with annual rainfall as low as 400 mm. Has some tolerance to drought but is not tolerant to water logging. It requires high light intensity. Optimum temperature range is 19–27°C. It prefers well drained, medium to high fertility soils but can be grown successfully on sandy soils and will tolerate and be productive in a very wide soil acidity range (*p*H 5.0–8.0).

Cultural requirements

It responds to shorter day lengths, flowering being also stimulated by higher (21°C) night temperatures. Period between flowering and mature seed is long with pods starting to ripen 2–3 months after flowering. Mucuna usually dies off 45–60 days after producing seed. Some regrowth is possible if plants are cut before flowering. It does not require a high degree of land preparation. Best results are with drilling with an arrangement of about 1 m between rows and 20–80 cm between plants (20–40 kg/ha seed); Seeds are large and so seeding depth can be as deep as 10 cm but mostly 3–7 cm. Seed does not require scarification.

Despite its ability to grow on soils with low available soil P, Mucuna responds to phosphorus applications. There are also reports of responses to applications of lime on acid soils either from amelioration of *p*H or from Mg and Ca applications. Velvet bean is very vigorous and its growth suppresses companion species. If

grown in interrow cropping systems, it should be sown well after the other crop such as maize, as much as 45 days after, to overcome this competition. Sowing two weeks after maize results in a good mix for silage.

Harvesting and yield

Varieties mature in 100–280 days after start of flowering. Maturation is not uniform. High levels of grain production are possible (2–20 q/ha). Plants need support because of the size and weight of pods. •

CHAPTER 16

Root Crops

ROOT crop is a plant that stores edible material in the root (edible underground plant structure).The primary function of these underground storage structures is to store nutrient reserves to ensure the plants' survival. The important commercial crops grown under this group are carrot, radish, turnip and beet root. All these crops thrive well in cool season. However, a number of varieties of carrot, radish, turnip, beet root, have been developed which grow well in a comparatively warm season. All the root crops though belonging to a number of different families need nearly the same cultural requirements.

CARROT

Fig. 13. Carrot

Carrot is said to be the native of Europe, Asia and North Africa and possibly North and South America. It was probably cultivated by the ancients but was not a common food plant. Asiatic carrot types have probably originated from central Asia. In Hindi it is known as *Gajar.* Carrot is the most common root vegetable grown all over the country.

Carrot is an important vegetable in European countries, USA, Asia and India. It is grown in Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Asom, Haryana. In India it is grown in an area of 62,000 ha with a production of 1153,000 tonne and productivity of 18.6 tonne/ha (NHB, 2011).

The Asiatic carrots are generally red colored because of anthocyanin pigment. The European types are orange because of carotene, a precursor of vitamin A. In India, mostly Asiatic carrots are grown probably due to appeal for red pigment. It is taken as raw as salad and as a cooked vegetable. It has got some medicinal values also in ayurvedic medicines. A black type of carrot is used to prepare *kanji*, a beverage very common in few states. Fresh edible carrot contains 88.6% water, 1.1% protein, 0.2% fat, 9.1 per cent carbohydrates, 1.1 per cent fibre, 12,000 IU vitamin A, along with traces of vitamin B_1, B_2 and C and minerals (Bharadwaj 2004).

Botany

Carrot (*Daucus carota* L.) belongs to the family Umbelliferae/Apiaceae. It has got fleshy edible root portion which is designated as conical root botanically. The genus Daucus has 22 differing species of hairy annuals and biennials that are found all over the world. These plants prefer to grow in temperate coastal regions. The specie-carota and sub-specie-sativa look very similar, with feathery divided leaves, which resemble fern leaves. The plant produces small white flowers in flat topped and rounded clusters in summer. The fruit is oval with spiky ridges. The large succulent tap-root of the carrot (sativa) distinguishes it from the wild carrot which has a thin white inedible root. The carrot root is known in the west for its distinctive orange color, but Asian varieties come in various colors: orange to yellow, white, purple, and dark red.

There are two distinct groups of carrot, i.e. European or temperate and Asiatic or tropical types. The European varieties are of orange colored and are rich in carotene. They are low yielder (100–150 q/ha) and perform well in cool climate. The European types produce good roots in the plains but fail to produce seeds in the plains. Root ends are blunt in European types.

The Asiatic varieties are of red or purple colour and poor in carotene. They are high yields (200–250 q/ha) and can be grown in warm climate. The Asiatic types produce roots and seeds freely in the plains. The Asiatic types have their root ends predominantly conical. Asiatic types are tropical and subtropical annuals, no chilling is required for their seed production; the roots have more anthocyanin content, high sugar content, more core, heavy top; core is not coloured; early maturing.

Breeding

Carrot is a cross-pollinated crop with protandrous bisexual flowers. In Asiatic carrots, a good number of local useful strains are available in various regions of the country, and some of them are very high yielding. Because of the pleasant flavour liked by the Indians it has larger production and consumption than the European types which have a different flavour but excellent texture. In the plains at some of the research stations, it has been possible to maintain and evaluate some of the useful strains for utilization in breeding programmes. Also efforts were made at IARI, New Delhi and its sub-station in Kullu Valley, Himachal Pradesh, to cross the useful strains of the Asiatic and exotic strains, with an intention to incorporate good root qualities of European types into high yielding Asiatic types. A carrot variety Pusa Kesar which has good qualities of both Asiatic and European types with an ability to produce seeds in the plains has been developed. In 1985, another Asiatic carrot Pusa Meghali was evolved from a cross between Pusa Kesar and Nantes. Also information has been gathered on the genetics of various economic characters in Asiatic carrots. It was reported that splitting was a varietal characteristic and was governed partially by genetic factors in addition to the effect of spacing and nitrogen application. Efforts have been made to breed hybrid carrots by using male sterile lines. The new cytoplasmic male stenile system in an alloplasmic form of orange carrot is a cross between the wild carrot *Daucus gummifera* and the cultivated carrot *D.carota*. Recently the

heat tolerant carrots like Kuroda, and New Kuroda, having deep orange coloured and stumped roots, are being imported from Japan and South Korea by private seed companies. They are becoming popular in the southern states (Nath *et al.* 2002).

Improved cultivars

Asiatic or tropical cultivars

Pusa Rudhira: This is released by IARI, New Delhi. Average yield 330 q/ha. Roots have red coloured core with delayed bolting. Maturity 85–90 days.

Pusa Asita: This is released by IARI, New Delhi. Average yield 300 q/ha. Roots have self black coloured core and it is a late bolter. Maturity 95–100 days.

Pusa Vrishti: This is released by IARI, New Delhi. Roots have red coloured core. It is a new heat tolerant tropical carrot variety. It is suitable for early sowing beginning in July under north Indian plains. Average yield 250 q/ha. Maturity 85–90 days.

Pusa Kesar: Developed by IARI, New Delhi. Red coloured roots and self coloured core. Suitable for early sowing (mid August - early October). It bolts a fortnight later in red types. Maturity 90–110 days. Yield 300 q/ha.

Pusa Meghali: Developed by IARI, New Delhi. Orange coloured roots, self coloured core and short top. Suitable for early sowing (mid August-early October). Maturity 100–110 days. Yield 250 q/ha.

Arka Suraj: Developed by IIHR, Bengaluru. The variety was developed by pedigree selection between Nantes and IIHR 253. Deep orange roots with self coloured core, conical shape, root length is 15–18 cm with TSS 8–10%. Tolerant to Powdery mildew and nematode. It flowers and set seeds under tropical condition.

Ooty 1: This variety is released by TNAU. The roots are long and slightly tapering with attractive deep orange colour. It is suitable for growing in hilly areas at an altitude of above 1,800 m. The crop is medium in duration (100–110 days) and suitable for growing in all the three seasons throughout the year. The central core is thin, fleshy and palatable. The crop is free from pre-mature bolting and resistant to powdery mildew, leaf spot and drought. The roots are rich in β-carotene. It yields 491 q/ha.

Pusa Nayanjyoti (F1): This is the first temperate carrot F1 hybrid of orange colour developed by IARI using CMS system. It is suitable for all carrot growing areas in temperate and tropical regions. The roots get ready for harvesting in 75–85 days. It is early by 10 days than that of traditional variety Pusa Yamdagni. Its roots are orange, uniform, attractive, smooth, cylindrical, stumpy with a thin tail having small indistinct self coloured core. It is rich in β-carotene content (7.552 mg/100 g fresh weight). The average root yield is 396 q/ha.

Pusa Vasuda (F1): This is released by IARI, New Delhi. First public sector tropical carrot F1 hybrid developed using CMS system. Self-red coloured carrot hybrid. High in total carotenoids, lycopene, TSS and minerals.

European or temperate cultivars

Nantes Half Long: Cylindrical, stumpy, orange coloured roots, self-coloured

core. Suitable for sowing from mid October - early December. Maturity 100–120 days. Yield 100–125 q/ha.

Pusa Yamdagni: Developed by IARI, New Delhi. Roots with orange flesh and self-coloured core. Suitable for sowing from mid October - early December. Maturity 100–110 days. Yield 150–200 q/ha.

Early Nantes: Roots with orange flesh and self-coloured core. Almost cylindrical roots, terminating abruptly in small thin tail. Suitable for sowing from mid October - early December. Maturity 90–100 days. Yield 100–120 q/ha.

Chantaney: Roots with orange coloured flesh and self-coloured core, thick at the shoulder with gradual tapering. Suitable for sowing from mid October - early December. Suitable for canning. Maturity 100–120 days. Yield 125–150 q/ha.

No. 29: Developed by IARI, New Delhi. Selection from a local variety. Roots light red, long, tapering and thin.

Sel-233: Roots are orange, semi-cylindrial, maturity duration 90–100 days.

Sel-21: Roots red with light orange core, quick growing. Suitable for pickles, candy and juice.

Imperator: Deep orange coloured roots, self-coloured core. Suitable for sowing from mid October - early December. Maturity 100–120 days. Yield 120–150 q/ha.

Zeno: Introduction from Germany. Roots long, orange, medium tops, maturity 110–120 days and suitable for Nilgiris.

Climate and soil

Carrot is a cool season crop. The climate and soil requirements of it are more or less the same as that of radish but it requires a relatively long growing season than radish. Though it can tolerate higher temperatures, the optimum temperature is 7.2–23.9°C for germination and 18.3- 23.9°C for better growth. Barnes (1936) reported that greenhouse grown carrots produced longest root between 10–15.6°C with poor colour and between 15.6–21.1°C with good colour. However, 23.9– 29.4°C temperature produced shortest root, but the shape was not affected by the temperature. During the development of root the colour changes from white to yellowish white, whitish yellow, light yellow, dark yellow, orange and then dark-orange gradually. The carotene content is reduced if the temperature goes below 15.6°C and above 21.1°C. Deep, well-drained, sandy loam soil, is preferred for an early crop. It does not grow well on highly acidic soil. Heavy soil may check the development of root and cause forked lateral roots.

Cultural requirements

Sowing time: The time of sowing of carrot is more or less the same as that of radish. In northern plains, seeds of temperate types are sown during October-December and that of Asiatic types are sown in August- early October. In southern and central parts of India it can be sown in January-February, June-July and October-November.

Land preparation and sowing: Carrot seeds are usually sown on ridges (10–15 cm high) or on flat beds (1.5 cm) in light soils. Commonly, the growers

broadcast the seeds but the proper method is to sow the seeds in rows, spaced 30 cm apart. The distance between ridges is 45 cm for Asiatic types and 30 cm for temperate types. The land is prepared by ploughing and harrowing. 25 tonne/ha of FYM is applied at the time of land preparation. Ridges and furrows are prepared. A fertilizer dose of 50 kg N, 50 kg P, 50 kg K/ha is applied on the sides of ridges in shallow furrows and covered with soil. The furrows are irrigated 2 days before sowing. Shallow sowing about 1.5 cm deep gives good gerrnination. Germination is slow and usually 10–15 days are required for seedlings to appear.It is desirable that at the time of sowing sufficient moisture should be there or light irrigation should be given immediately after sowing. It is better to soak the seeds in water for 12–24 hours before sowing to hasten germination.

For sowing carrot on level surface, the fields are arranged in small plots, convenient for irrigation and the seed mixed with fine soil or coarse sand is broadcast and the soil surface is raked to cover the seed lightly. Depending on the moisture available, the seeds germinate in 5–10 days. Initially thick sowing of seeds should be done. The thinning may be required after germination to maintain 5–7 cm distance between the plants within the rows. It requires 6- 9 kg of seed to plant an hectare of area.

Intercultural operations

In the light soils, the first irrigation may be given soon after sowing which may be followed by next at 4–6 days interval depending on the soil moisture available. In the early stage the crop should be kept free of weeds which may be done by frequent hoeings. It facilitates in proper soil aeration and root development. 50 kg N/ha is given as top dressing after 30 days of sowing. Earthing up should be done to cover the developing roots with soil and thus to prevent discolouration of roots. When tops show aboveground, thin out the seedlings to maintain 3–4 cm spacing. About 3 or 4 weeks later when baby carrots have formed thin again to maintain 8–10 cm spacing from plant to plant.

Physiological disorders

Forking or branching: In carrot forking or branching of roots can occur when undecomposed organic manure is applied. The root growth is also affected due to the hard pan below the top soil.

Splitting or cracking: Splitting or cracking of carrot roots may be due to irregular water supply or any disparity in nitrogen application. Calcium deficiency may cause cavities in the cortex of the roots.

Pest and disease management

Diseases

***Leaf spot** (Cercospora carotae):* Infected leaves shows leisions on leaves, petioles, floral parts. Brown to black spots appears on leaves. Control measures include: seed treatment with hot water (50°C) for 15 minutes and a foliar spray of copper oxychlocide (0.3%).

***Damping off** (Pythium aphinidermatum):* Affected plants start rotting in the

collar region of seedlings. It is generally observed when the drainage is poor in the soils. The seeds should be treated with captan @ 3 g/kg of seed.

Powdery mildew (Eryciphe polygoni): Spray wettable sulphur (0.3%) or copper oxychloride (0.3%) after 4 weeks of sowing to control powdery mildew and leaf spot diseases respectively and repeat the spray schedules as per the need.

Insect pests

Carrot fly (Psila rosae): Small pale yellow maggots of this insect bore into the roots. The foliage become reddish and plants show wilting. Control measures include destruction of infected plants and growing onion in between the rows of carrot which helps in repelling the flies due to its leaves having stronger smell than the carrot leaves.

Cut worms (Agrotis ipsilon): For cut worm management collect and destroy groups of egg masses located on the lower surface of the leaves and also young congregating larvae. When the grown up caterpillars attain cut worm status, use baiting with methomyl. For this purpose, mix 2 kg *jaggery* with 10 kg rice or wheat bran in the morning. In the evening mix 250 g of methomyl carefully and sprinkle over the ridges. Cut worms get attracted to fermenting *jaggery*, eat the mixture and get killed. Repeat the baiting for 1–2 more days to get complete control.

Harvesting and yield

Carrots for fresh market are harvested when majority of the roots are 2.5 to 3.5 cm in diameter at the crown. They can be harvested 110–120 days after sowing depending on the variety. Carrot may be adjudged for harvesting at the marketable stage depending on the size of the root. Care should be taken that they should not grow beyond the marketable stage as they become fluffy and unfit for consumption. The common Asiatic varieties attain the marketable stage at 2.5- 4 cm diameter at the upper end. The roots which are grown on ridges are easy to be pulled out than those in flat beds. In both the cases it is advisable to give light irrigation before harvesting which facilitates pulling out the roots from the soil without any damage.

The Asiatic varieties yield higher than the European varieties. The Asiatic varieties yield 200–250 q/ha whereas, European varieties yield 100–150 q/ha.

The roots are washed, cleaned and bunched in a fixed number, say half-a-dozen together. Carrots can be stored at room temperature for 3–4 days under ordinary conditions. At temperatures of 0°C with 90–95% relative humidity they can be stored for seven weeks..

Seed production

Only the Asiatic varieties produce seeds in the plains. The European varieties do not produce seed in the plains; hence, their seed production is limited to the hills only. Since it is a cross-pollinated crop, every care should be taken to keep the two varieties away from each other and the isolation distance given to produce foundation seed is about 1,000 m and for certified seed it is 800 m. Usually good quality and high yielding roots of a variety are selected at the root marketable stage and transplanted in well prepared fields after giving proper root and shoot

cuts to ensure better quality and higher seed yield. The selected roots are planted at a distance of 75 cm × 20 cm. It is reported that the stecklings should be given the treatment of one third shoot cut and one fourth to one half root cut to obtain better quality and higher seed yield. If possible, the seed growers may not harvest the seeds of third order umbel, which has poor seed germination, thereby ensuring better germination percentage from the seeds collected from the first two orders of umbel.

The off-type plants including premature bolters should be rogued out before flowering of the stalks. The harvesting is done when the secondary umbels are fully ripe and the third order umbels have begun to turn brown. Shattering is not a serious problem in carrots. The plants can be pulled and stacked for curing. Threshing is done by wooden rollers when the stem becomes brittle.

A seed yield of 450–550 kg/ha from the European varieties and 800–1,000 kg/ha from the Asiatic varieties can be obtained.

RADISH

Fig. 14. Radish

Radish is probably originated in Western Asia, was cultivated in ancient Egypt, Greece and Rome. It is now spread through-out the world. In Hindi it is known as *mooli.* It is grown widely in northern and southern plains as well as in the hills. In India it is grown in an area of 160,000 ha with a production of 2286,000 tonne and productivity of 14.3 tonne/ha (NHB, 2011).

Radish is an important root vegetable grown all over the country. The enlarged succulent taproot is used as vegetable both raw as salad and cooked in various ways. The tender leaves are also often used as a leafy vegetable. Being a quick growing crop it can be planted as an inter crop or companion crop in other vegetables.

It is consumed almost in every house whether rich or poor. Radish green is very rich in vitamin A, B and C with little of carbohydrates, iron and protein. It is eaten both raw as salad or cooked in various ways. It has a cooling effect and it increases the appetite. It has some medicinal values too. 100 g of edible roots contain 93.7% water, 4.2% carbohydrates, 1.1% protein, 0.1 per cent fat, 0.7% fibre, 30 IU vitamin A, 24 mg vitamin C, 37 mg calcium, 31 mg phosphorus, 260 mg potassium, 15 mg magnesium, 37 mg sulphur and chlorine.

Botany

Radish (*Raphanus sativus* L., 2n=18) is a member of Cruciferae family. Depending upon flowering radishes may be classified as annual and biennial. The annuals are of mainly tropical origin and do not require chilling for flower induction while the biennials are of temperate origin and require chilling for

flowering and seed production. The enlarged edible roots are fusiform botanically which may differ in colour from white to red. There are two distinct genetical groups in radish. The Asiatic varieties which are primarily for tropical climate, produce edible roots in the first season and seeds in the second season as a biennial crop, whereas the exotic or European varieties produce roots in the plains of tropical and sub-tropical climate and seeds in the hills of temperate climate.

Both types produce fleshy tap roots together with a rosette of leaves arising from a shortened stem. The inflorescence is the typical terminal raceme of the crucifers, and the flowers are white, rose or lilac in colour. Radish is highly cross pollinated crop, pollination occurs primarily by honeybees. Flowers open during the day time from 8 AM onward. Dehiscence generally takes place at warmer temperature condition. Radish fruits differ from that of other crucifers in that it is not a siliqua but a true pod, about 2.5 to 7.5 cm with a pithy interior.

Breeding

Radish is a cross-pollinated crop. The commonly adopted procedures for breeding are mass selection, recurrent selection, hybridization and heterosis. The F_1 hybrids are produced by single crosses, or double crosses. Transgression of useful traits is possible by wide interspecific crosses between *Raphanus* and *Brassica* species by protoplast fusion and genetic engineering. These aspects are important for developing commercial cultivated species of the crop. Some studies on pollen morphology and physiology in radish have been reported. Different useful strains of Asiatic types have been reported from different regions of the country. A good number of temperate and Asiatic varieties were also introduced and some of them have been grown as commercial varieties for decades, but their seed production has been possible only in Kashmir, Kullu Valley and Nilgiri Hills. Usually the Asiatic types are more pungent than the temperate ones. Attempts have been made to improve upon the Asiatic strains by crossing with the exotic varieties to obtain new varieties with root qualities of temperate types and ability to produce seeds in the plains. An important achievement in this direction has been the release of the new radish variety 'Pusa Himani'. Emphasis has also been laid on developing varieties resistant to diseases. 'Arka Nishant', is the variety developed at IIHR, Bengaluru in 1972 which produces high yield with the better quality roots in the southern region. Male sterile line has also been used for hybrid seed production in other countries. In radish Ogura sterile cytoplasm is widely distributed in wild Japanese radish (Nath *et al.* 2002).

Improved cultivars

Asiatic cultivars

Japanese White: Roots are 35–40 cm long, stumpy in shape, pure white, less pungent or sweet in taste. Leaves are of medium size and grayish green. Suitable for sowing from October - December. Maturity 60–65 days. Yield 350–400 q/ha.

Pusa Desi: Developed by IARI, New Delhi. Roots are 30–35 cm long, tapering, white with green stem end and mildly pungent in taste. Leaves are of medium

size and green. Suitable for sowing from August - October. Maturity 50–55 days. Yield 300 q/ha.

Pusa Reshmi: Developed by IARI, New Delhi. Roots are 30–35 cm long, tapering, white with green stem end, mildly pungent in taste. Leaves are of small to medium size and green. Suitable for sowing from October - December. Maturity 60–65 days. Yield 350–400 q/ha.

Pusa Himani: Developed by IARI, New Delhi. Roots are 30–35 cm long, tapering, white with green stem end, mildly pungent in taste. Leaves are of small in size and dark green. Suitable for sowing from December - February in plains and during summer season in the hills. Maturity 60 - 65 days. Yield 300–325 q/ha.

Pusa Chetki: Developed by IARI, New Delhi. Roots are 15–20 cm long, stumpy in shape, pure white and mildly pungent or sweet in taste. Leaves are of medium in size, erect, soft and green. Suitable for sowing from mid April - August. Maturity 40 days. Yield 200–250 q/ha.

Pusa Mridula: This is released by IARI, New Delhi. Roots are globular with bright red skin, mildly pungent. Average yield 130 q/ha. Maturity 25 days.

Pusa Jamuni: First purple fleshed unique trait nutritionally rich radish variety. Distinct advantage in root size, shape, yield and consumer preference over the existing varieties. Higher anthocyanins and ascorbic acid.

Pusa Gulabi: This is released by IARI, New Delhi. First entire pink fleshed unique trait nutritional rich radish variety. Medium root size, cylindrical shape, optimal yield and consumer preference over the existing varieties. High total carotenoids, anthocyanins and optimal ascorbic acid.

Arka Nishant: Developed by IIHR, Bengaluru. It is an Asiatic variety. Matures within 45–55 days. Roots are medium sized (25 cm × 3.4 cm), marble white, crisp texture with pleasant aroma; free from early bolting, pithiness, splitting and forking, each root weighing 300–400 g. Root and shoot length ratio is 1: 1. Pungency is mild. It yields 200–300 q/ha.

Punjab Safed: Developed by PAU, Ludhiana. Roots are pure white, tapering, smooth, mild in taste, 30–40 cm long and 3–5 cm thick.

CO 1: This variety is released by TNAU. The crop duration ranges from 40-45 days and hence suitable for cropping systems. It yields 200–250 q/ha. The roots are milky white, long (22 cm), thick (12.5 cm girth) and each weighs 220 g. The roots contain 10.9 mg of vitamin C per 100 g and 1.20% crude fibre. This variety is suitable for growing all the year round under different cropping systems. It bolts and sets seeds in the plain.

European cultivars

White Icicle: Roots are small (8–10 cm long), thin, pure white, tapering, sweet in taste. Suitable for sowing in kitchen garden or container garden from October - January. Maturity 30 days. Yield 50 q/ha.

Rapid Red White Tipped: Roots are small, round or globular, upper portion of the roots is red and lower portion is white, sweet in taste. Suitable for sowing in kitchen garden or container garden from October - January. Maturity 25 days. Yield 50 q/ha.

Climate and soil

It is a cool season crop, but the Asiatic varieties can resist more heat than the European or temperate varieties. It attains best flavour, texture and size at 10–15.6 °C. A long day as well as high temperatures lead to bolting without adequate root formation. During the hot-weather the roots become tough and pungent before reaching the edible size and therefore should be harvested while young and small in size. Radish is more pungent at higher temperature. Pungency decreases with the advent of cooler temperature. The temperate types are generally small, mild pungent in taste and mostly used as a salad. It may be grown in all kinds of soils but the best results are obtained on sandy loam soils which are friable and contain high amount of humus. Usually the heavy soils produce rough, ill-shaped roots with number of small fibrous laterals. The field should be prepared with at least 4–5 ploughings so as to make the soil very loose and smooth.

Cultural requirements

Planting time: Since, it is a cool season crop its cultivation is preferred during winter season in the plains. It can be sown any time between September-January in the northern plains as it is not affected either by frost or by extreme cold-weather conditions. It is grown from March - August in hills. In the regions where summer is mild, it can be grown throughout the year except during few months of summer. In Bengaluru, the radish roots are available practically for 8- 10 months of the year but the best edible roots are available during November-December only. The temperate types are generally not planted till October. The time of sowing in radish varies from region to region. As it is non-tolerant crop for high temperature, August-October is the suitable season for sowing.

Land preparation and sowing: Bring the soil to a fine tilth by ploughing the land 3–4 times. Incorporate 25 tonne/ha of well rotten farm-yard manure (FYM) after the first ploughing. Prepare continuous ridges and furrows of convenient length. A spacing of 25–30 cm between the two ridges may be kept depending on the variety grown and spacing between plants within the rows be maintained at 8–10 cm, by thinning out the extra seedlings 15 days after sowing. Apply the fertilizer mixture (@ 50 kg N, 100 kg P and 50 kg K/ha) at bottom of the ridge and cover it with soil. Irrigate the furrows 2 days before sowing the seeds.

Seeds are usually sown on ridges to facilitate good root production. Shallow furrows of 2 cm depth are opened on the ridges using a stick. The seeds are thinly sown in the shallow furrows and covered with soil or pulverized manure. A light irrigation is given immediately after sowing. For continuous supply the seeds of Asiatic varieties are sown ones in 15 days and of European varieties ones in eight days.

Intercultural operations

It is necessary that enough of soil moisture is available to help uniform seed germination and growth of the plant. If enough soil moisture is not available at the time of sowing, the first irrigation should be given immediately after sowing. It is advantageous in case of light soils but it hinders the germination in heavy soil where the soil surface has become dry with hard crust formation before the

seed has sprouted and broken through the soil. In this case, it is always safer if the sowing is done when already enough of soil moisture is available for germination in heavy soils. Depending on the season and the soil moisture available, it may be irrigated once or twice a week. It should be irrigated very frequently, but care should be taken that the field may not become dry and compact so that the root development is not checked.

Weeding should be done at regular intervals to keep down the weeds. Shallow hoeing may be necessary to facilitate root growth. Spacing between plants within the rows should be maintained at 8–10 cm, by thinning out the extra seedlings 15 days after sowing.

Top dress the crop with 50 kg N/ha 25–30 days after sowing (for Asiatic varieties only) and do earthing up which prevents discoloration of roots exposed to the atmosphere and to get better quality roots. When the roots have started growing, earthing up should be done for enlarged root production, otherwise the growing roots may come above the soil surface.

Pest and disease management

Diseases

White rust (Albugo candida): In some areas, it is a very serious disease of radish. It produces a white powdery substance in patches on the under surface of the leaves. It mainly appears on the leaves and flowering shoots which get deformed and bear only malformed flowers. The disease can be controlled effectively by spraying chlorothalonil (0.2%) or mancozeb (0.2%) or copper hydroxide (0.2%).

Root rot (Erwinia rhapontici): It results in rotthing of pith tissues and cavity formation and the plant wilts and dies. Root dip in Agrimycin @ 100 ppm is recommended.

Insect pests

Aphids (Brevicoryne* sp., *Myzus* sp.*): This pest attacks most of the *Cruciferous* crops and persists on the alternate hosts throughout the year. The cloudy and humid conditions are favourable for their quick multiplication. In case of heavy infestation, the plants are completely devitalized, leaves and shoots curl up, get yellowed and finally die. For control, spray the crop with malathion @ 2 ml/l of water at 10–15 days interval.

Mustard saw fly (Athalia* sp.*): This is a common pest of radish and turnip. It appears when the crops are in flowering and at vegetative stage. The damage is done by the grub by biting hole in the leaves and fruits. Collect and destroy mustard saw fly larvae and spray neem soap 1% or quinalphos (2.5 ml/L) for controling mustard saw fly larvae.

Flea beetle (Phyllotreta* sp.*): In some areas, it becomes a very serious pest on the vegetative parts of the plant which are eaten by this pest. It can be controlled by spraying with spray chlorpyriphos (0.05%) or quinalphos (0.05%), if required only.

Harvesting and yield

Irrigate the crop before pulling out the roots as the soil should contain ample

moisture for easy pulling of roots. The European varieties should be uprooted 25–30 days after sowing (DAS). They will become fluffy and pithy (which are unfit for consumption) if kept in the field for a longer time.

The Asiatic varieties can be harvested 45–90 DAS and remain edible much longer than the European varieties. The maturity of the roots for marketing will depend on the size of the roots as well as on the variety. It is necessary that the roots are harvested at the right stage because they tend to become fluffy and unmarketable thereafter. The roots should be harvested at tender stage. Delay in harvesting may result in pithiness of roots. The roots are washed and bunched together along with the shoots for marketing purposes. Roots can be stored at room temperature for 3–4 days without impairing its quality much, and for two months in the cold storage at 0° C and 90–95% relative humidity.

The Asiatic improved varieties produce 150–250 q/ha of roots in 40–60 days, whereas the temperate varieties produce 50–80 q/ha in 25–30 days.

Seed production

The land should be selected considering the fact that the same kind of crop was not grown within the previous two years to contain seed borne diseases beyond maximum permissible levels. About 4–6 kg seed is required per hectare of land. Cultural practices for seed production are similar to the crop grown for roots. Two methods of seed production, viz. seed-to-seed and root-to-seed methods are employed for radish seed production. Seed-to-seed method is preferred for raising certified seed. This method is not recommended, as the selection of good roots cannot be made and off-type plants which are not true to variety cannot be removed. Also the seed quality and yield are affected. The nucleus seed, however, is invariably produced by root-to-seed method. In this method the roots are uprooted and planted again before the onset of reproduction phase.

Root-to-seed method: In root-to-seed method, fully matured roots (before pith development) are harvested, true-to-type roots are selected and after giving proper root and shoot cuts they are transplanted in a well prepared field. Highest seed yield in is obtained by giving 1/4th root cut and 2/3rd shoot cut. The selection and roguing are done on the basis of foliage characters, root shape, size, colour, flesh colour, pithiness, pungency and bolting behavior. Small, deformed, diseased and other undesirable roots are discarded. Hairy, forked roots and early or late bolters are also removed. For high yield of good quality seeds, radish stecklings are planted at a spacing of 45 cm × 30 cm. The field prepared for steckling planting should be fertilized with 50 kg N and 50 kg K/ha.

Seed-to-seed method: Usually commercial market seed is grown by this simpler method. The annual radish crop is sown in mid September through October at a spacing of 45 cm × 45 cm in a well prepared land. The crop is allowed to grow and produce seed at their original position (*in situ*). Rigorous roguing should be used to raise seed-to-seed crop.

Radish is a cross-pollinated crop and honeybees are mainly responsible for pollination. Radishes will cross other radishes including daikon, but not turnips (*Brassica rapa*) or other members of the cabbage family. Seed fields must be isolated from other variety of radish, and the same variety not conforming to

varietal purity requirements by at least 1,600 m for foundation seed and 1,000 m for certified seed production. Honeybees are the chief pollinating agents. It is that seed yield in radish is greatly influenced by the number of honey bees visiting the flowers. Those beehives may be provided at the time of flowering, in the field for higher seed yield.

Weeds, especially wild radish, wild turnip, wild mustard should be all removed from the radish field before bolting to avoid possible cross-pollination. One or two irrigation may be given after flowering which results in better seed yield. Sometimes staking is done to provide support to the seed stalk.

The seed plants are allowed to mature fully before harvesting, since there is no natural dehiscence, and there is often considerable difficulty in threshing the seed from the pod. Plants are cut when most of the pods are brown. Pick pods after they dry completely on the plant. Pick every day or two, as the pods will break open naturally to release their seeds soon after drying.

The crop is cut by sickle and brought to the threshing floor for thoroughly drying. The drier the pods, the more easily will they break open during threshing process. Threshing can be done by beating with sticks. The seed after sifting should be dried to 6–8% moisture content before storage. The average seed yield ranges from 800–1000 kg/ha. Radish seeds can last 4 or 5 years if properly stored.

TURNIP

Fig. 15. Turnip

It is not definitely known from where the turnip originated but it is said to be known growing wild in Russia and Siberia. Some regard it as central and western China while others assign it to middle Asia, Punjab and Kashmir. It has been grown in India since a long time. In Hindi it is known as *shalgum.* Turnip is grown in almost all the regions in northern plains along with radish and carrot. It is very popular especially in Jammu and Kashmir, Punjab, Himachal Pradesh and western Uttar Pradesh.

The turnip is primarily used as a vegetable and to a limited extent it forms the ingredient of salad preparation. Turnip greens are sometimes used as vegetable but are extensively utilized as green fodder. Turnip greens are good source of calcium, iron and vitamin A and C and contain appreciable amount of vitamin B also. The roots contain vitamin B and C in appreciable quantities. The 100 g edible root contains 91% water, 7.6 per cent carbohydrates, 0.5% protein and 0.6% mineral water (Bharadwaj, 2004). European types of turnip are relatively sweet and more palatable and may be eaten sometimes raw. The Asiatic turnips prepare good pickles also. In Jammu and Kashmir it is used in several delicious dishes including the meat.

Botany

Turnip (*Brassica rapa* L.) belongs to the family Cruciferae. The turnip is grown primarily for its enlarged root which is napiform consisting of the hypocotyl, which swells and becomes spherical. It has hermaphrodite flowers and is highly cross-pollinated mainly due to self incompatibility nature. It is an herbaceous annual for the root production, whereas it is biennial for the seed production. As in carrot and radish, this crop also has two distinct groups, viz. Asiatic and European types. As in carrot and radish, the Asiatic turnip types produce seeds freely in the plains, whereas the European types do not produce seeds in the plains. Asiatic types are more pungent.

Breeding

Turnip is cross-pollinated hence inbreeding is done in this crop. The important uses of inbreeding in cross-pollinated crops are to obtain uniformity in plant characters, to improve yield by individual plant selection and to combine suitable inbred lines in the production of hybrids and synthetics. Self-fertilization is the most intense form of inbreeding. Until 3^{rd} or 4^{th} generations, inbreeding depression is not much. Mass selection, progeny selection and hybridization are the common breeding systems in turnip. Hybridization between Asiatic and temperate types has been effective in this crop. A number of good genetic stocks of Asiatic and European types are available in India. Some of them are very good varieties. Efforts were made in the past to maintain some of the Asiatic strains, but no intensive breeding work was taken up. However, an interesting achievement has been the release of the new varieties Pusa Kanchan (Singh, 1963), Pusa Sweti (Asiatic type), Pusa Chandrima (European type) from IARI, New Delhi. Pusa Kanchan has been selected from cross between an Asiatic variety Local Red Round and the European variety Golden Ball. It has good qualities of both Asiatic and European type of varieties with ability to produce seed freely in the plains (Nath *et al.* 2002).

Improved cultivars

Pusa Sweti: Developed by IARI, New Delhi. Roots are pure white, round and slightly flat with rat tail habit. Flesh white, sweet and mildly flavoured. Leaves are green and small to medium in size. Suitable for sowing from early August - September. Maturity 45–50 days. Yield 250–300 q/ha.

Purple Top White Globe: Roots are large, round, smooth, upper part of skin purplish and lower part is creamy white. Flesh white, firm, crisp and mildly sweet. Leaves are dark green and erect. Suitable for sowing from October - December. Maturity 60–65 days. Yield 350 q/ha.

Pusa Swarnima: Developed by IARI, New Delhi. Roots are large, flattish-round, pale amber coloured, rich in carotene content and sweet in taste. Leaves are medium and green. Suitable for sowing from October - December. Maturity 65–70 days. Yield 350–375 q/ha.

Pusa Chandrima: Developed by IARI, New Delhi. Roots are medium to large, smooth, pure white, sweet in taste. Leaves are medium and green. Suitable for sowing from October - December. Maturity 60–65 days. Yield 350 q/ha.

Golden Ball: The roots are perfectly globe shaped, medium sized and smooth. Has bright creamy yellow skin and pale amber coloured flesh of fine texture and flavour. The top is small, erect with cut leaves.

Snow Ball: It is an early variety with medium sized roots. Roots are round, smooth with pure white skin, whereas, the flesh is white, finely grained, sweet and tender. It has a small erect top with medium yellow green and cut leaves.

Early Milan Red Top: It is an extra early 45 day variety. The roots are deep flat with purplish red tops and white underneath. The flesh is pure white, well grained, crisp and mildly pungent. The tops are very small with only 4 - 6 sessile leaves. It is a very high yielding variety.

Pusa Kanchan: Developed by IARI, New Delhi. Selection from a cross between 'Asiatic Red' and 'Golden Ball'. Its roots look just like the 'Local Red Round' turnip from which it differs in having creamy yellow flesh. The roots stay longer in the field without getting spongy. The leaf top is shorter than the local. It produces seed satisfactorily in the plains, though the seed is harvested a fortnight later than the 'Local Red'. It has excellent flavour and taste.

Punjab Safed 4: Developed by PAU, Ludhiana. A selection from local cultivar. Roots are pure white, round medium size and mild taste.

Climate and soil

Its climatic and soil requirements are more or less the same as that of radish and carrot. Asiatic varieties are sown earlier, requiring warmer conditions than the European types. Higher ascorbic acid content is obtained at higher light intensity.

Cultural requirements

The planting requirements are more or less the same as that of radish. Depending on the fertility status of the soils various fertilizer recommendations have been made. 25 tonne/ha of FYM, 50 kg N, 50 kg P, and 50 kg K/ha is applied as basal dose before sowing. Sowing is done in hills from March- May and in the plains from July- September (Asiatic) and October- December (European). It is sown in rows 30 cm apart. After thick sowing within the row, plants are thinned out and spaced at 10–15 cm. It gives a maximum seed germination of 90–95% and the seed remains viable for 4 years under good storage conditions. Seed germination is quicker in turnip and it makes rapid growth. The seed requirement is about 2.5–3.5 kg/ha.

Intercultural operations

One or two weedings should be done to remove the weeds and to conserve moisture. Irrigation depends on the soil type. First irrigation can be given after the germination. The subsequent irrigations are given for every 8–10 days. 50 kg N/ha is given as topdressing at the time of knob formation and earthing up is done.

Pest and disease management

The diseases which are common to radish also damage turnip. However, the

disease phyllody causes severe damage to the turnip crop meant for seed production in the hills. It shows malformation of flowering shoots and the entire plant may show this character. Such plants do not bear normal pods. Further spread of the disease can be checked by pulling out and burying down the affected plants.

Aphids and mustard saw fly are the common insect pests of turnip which have already been discussed under radish.

Harvesting and yield

The turnip roots are harvested when they are tender and attain the marketable size depending on the variety. The size ranges from 5 to 10 cm in diameter. They soon become fibrous and hard if they are allowed to grow beyond the marketable stage. They need to be handled gently as in the case of radish. It produces edible roots from 185–210 q/ha depending on the variety used.

The edible roots could be stored for two to three days at room conditions, whereas they can be stored for a longer period under cold storage. At a temperature of 0°C and 90–95% relative humidity, it can be stored up to 8–16 weeks.

Seed production

Cultural requirements for seed production are similar to those for vegetable production. Turnips are in the same species and will cross with Chinese mustards and Chinese cabbages and must be isolated from Chinese mustards and Chinese cabbages by 1,600 m of separation. Since it is a cross-pollinated crop the two varieties must be isolated by 1,600 m apart to avoid any out crossing to produce foundation seed.

Only the Asiatic varieties are able to produce seeds in the plains. As in the case of radish and carrot they require proper root and shoot cut to produce high quality seeds. This is not preferred in the case of the European varieties grown in the hills. The treated stecklings are immediately transplanted in the well prepared beds in such a way that the whole root is covered under the soil leaving the crown exposed. This is followed by irrigation. The optimum spacing given is 60 cm × 60 cm or 60 cm × 45 cm.

As with other Brassicaceae, allow seeds to ripen thoroughly on the plants before harvesting. Turnip seeds are prone to shattering and is, therefore, advisable to cut the whole crop when 60–70% of it turns yellowish brown but not dry. After 4–5 days, it is turned upside down and allowed to cure for another 4–5 days. It is then threshed with ordinary sticks and sifted with hand sifters. After thoroughly drying the seed in the sun it is graded by means of sifters and specified sieves thus separating the bad seeds. A seed yield of 600–800 kg/ha from the European varieties and 1,200–1,300 kg/ha from Asiatic varieties can be obtained. Turnip seeds can last 4 or 5 years if properly stored.

BEET ROOT

Garden beet or beet root or beet is probably a native of Europe, but some believe that it might have originated in mediterranean region or Asia. It is grown in almost all the states of India but not as common as radish, turnip and carrot. The common names of beet root are, table beet, blood turnip, red beet, garden beet, beet, and *chukandar.*

Beetroot is eaten raw as salad, cooked with other vegetables and with meat. Is also grown for processing. Sometimes, it is used in the preparation of pickles and *chutneys*. It is rich in protein, carbohydrates, Ca, P and vitamin C.

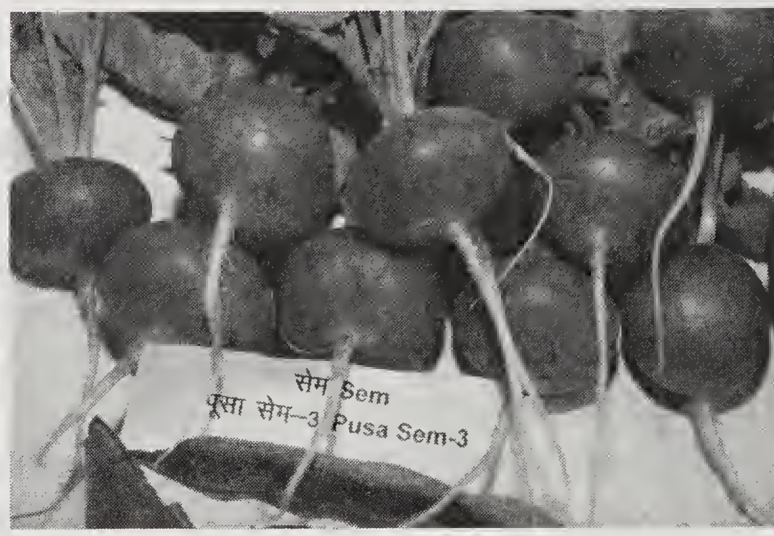

Fig. 16. Beet Root

Botany

The botanical name of beet root is *Beta vulgaris* L. var. *vulgaris.* (synonn: *B. v.* ssp. *v.* convar. *vulgaris* var. *vulgaris; Beta vulgaris* var *crassa*). It belongs to the family Amaranthaceae (formerly Chenopodiaceae). It is related to sugar beet (*B. v.* ssp. *v.* convar. *vulgaris* var. *altissima*), which is a major commercial crop due to its high concentrations of sucrose, which is extracted to produce table sugar. The roots of beet root are used as vegetable. It is primarily a cool season crop but grows well in warm-weather and hence can be grown during winter all over the plains.

It behaves as a biennial, producing a thickened root and a rosette of leaves first year, and flowers and seeds second year. Since it is a temperate type of crop it is only grown for edible roots in the plains and for seeds in the hills where temperate climate prevails. Flowers are small, sessile, bisexual, perfect and are borne in the axils of leaves in a group of 2–3, with 5 stamens, flowers produce abundant, small and light pollen grains which are carried by wind. Hence, the crop is highly cross-pollinated (a wind-pollinated crop). The flower stalk grows to a height of about 1.2 m. The calyx continues to grow after flowering, becomes corky and completely covers the seeds. This forms what is commonly called the beet seed or 'glomerule' or multigerm seeds, in reality is a fruit which contains usually 2–6 seeds. The true seeds are small, kidney shaped and brown. Each 'seed' is botanically a berry, and contains several actual seeds (multigerm seeds; 2–6 seeds) (breaking them apart would damage many of the seeds). The true seeds are small, kidney shaped and brown. The ovary forms a fruit which is embedded in the base of the perianth of the flower. Each fruit contains a single seed whose shape varies from round to kidney shaped. The ovaries are enclosed by the common receptacle of the flower cluster. A monogerm seed is formed when a flower occurs singly. The multigerm beet seed is formed by an aggregation of two or more flowers. Monogerm varieties can be precision drilled but multigerm varieties have to be singled. A typical beet seed is a fruit that can contain 2–3 embryos, which results in clumping. Monogerm beet seeds contain only one embryo. This feature eliminates thinning and results in superior uniformity. The diploid chromosome number is 2n=18. The seeds are viable for 2–6 years under normal conditions. Since it is a temperate type of crop it is only grown for edible roots in the plains and for seeds in the hills where temperate climate prevails.

The beet (*Beta vulgaris*) is best known in its numerous cultivated varieties, the most well known of which is the root vegetable known as the beet root or garden beet. However, other cultivated varieties include the leaf vegetable chard, as well

as the root vegetable sugar beet, which is important in the production of table sugar.

Three sub-species are typically recognised. All cultivated varieties fall into the subspecies *Beta vulgaris* subsp. *vulgaris*, while *Beta vulgaris* subsp. *maritima*, commonly known as the sea beet, is the wild ancestor of these, and is found throughout the Mediterranean, the Atlantic coast of Europe, the near East, and India. All cultivated varieties of the beet are grown for their taproots, leaves, or swollen midribs.

1. *Beta vulgaris* ssp. *vulgaris* convar. *cicla* (leaf beets) - The leaf beet group has a long history dating to the second millennium BC. The first cultivated forms were believed to have been domesticated in the Mediterranean, but were introduced to the Middle East, India, and finally China by 850 AD. These were used as medicinal plants in Ancient Greece and Medieval Europe. Their popularity declined in Europe following the introduction of spinach.

1) *B. v.* ssp. *v.* convar. *cicla.* var. *cicla* (spinach beet) - This variety is widely cultivated for its leaves, which are usually cooked like spinach.

2) *B. v.* ssp. *v.* convar. *cicla.* var. *flavescens* (chard) - Chard leaves have thick and fleshy midribs. Both the midribs and the leaf blades are used as vegetables, often in separate dishes. Some cultivars are also grown ornamentally for their coloured midribs. The thickened midribs are thought to have arisen from the spinach beet by mutation.

2. *Beta vulgaris* ssp. *vulgaris* convar. *vulgaris* (tuberous beets) - This grouping contains all beets grown for their thickened tubers rather than their leaves.

1) *B. v.* ssp. *v.* convar. *vulgaris* var. *altissima* (sugar beet) - The sugar beet is a major commercial crop due to its high concentrations of sucrose, which is extracted to produce table sugar. sugar beets, grown for making sugar from the long, thick root.

2) *B. v.* ssp. *v.* convar. *vulgaris* var. *vulgaris* (synon: *Beta vulgaris* var *crassa;* beet root or garden beet) - This is the red root vegetable that is most typically associated with the word 'beet'.

Breeding

Garden beet is a cross-pollinated crop. Selfing causes inbreeding depression. The methods adopted to improve beet root are mass selection, family selection and hybridization. It produces seeds in the temperate climate. Hence no attempt was made to breed varieties in the plains. All varieties that are under cultivation are from abroad. Some of the imported varieties were found to be suitable for commercial production in the plains. Recently efforts were made to select suitable sugar beet varieties for extracting sugar rather than beet varieties for vegetable. Some of the male sterile lines and monogerm seed varieties have also been reported for commercial utilization in the foreign countries.

Improved cultivars

Ooty 1: This variety is released by TNAU. It yields 314 q/ha of roots. The roots are blood red in colour with thin skin and good quality. 100 g of root pulp contains 1.52% protein, 10.25% carbohydrate and 6 mg of vitamin C. It can be

used as a salad. It is a direct sown crop, which can be harvested in 120–130 days, whereas transplanted crop comes to harvest in 135–150 days. It grows upto 40–52 cm in height

Crimson Globe: Roots are globular to flattened, medium red skin, flesh medium dark, crimson red with indistinct zoning, top medium to tall, large bright green leaves with maroon shades. Maturity 80–90 days. Yield 180 q/ha.

Detroit Dark Red: Roots are round with smooth, uniform, deep red skin. Flesh dark blood red with light red zoning, tender, top small, leaves dark green tinged with maroon. Maturity 80–100 days. Yield 180 q/ha.

Crosby Egyptian: Roots are flat globe with a small taproot and smooth outer surface. The flesh colour is dark purplish red with some indistinct zoning. The top is medium tall and green with red veins. Maturity 55–60 days. Yield 170 q/ha.

Early Wonder: Roots are flattened globe with a smooth, dark red skin. Flesh dark red with some light red zoning. Top is heavy, green with red veins. Maturity 55–60 days. Yield 160 q/ha.

Climate and soil

It is primarily a cool season crop but grows well in warm weather and hence can be grown during winter all over the plains. Beet root can withstand a slightly high temperature but not the severe freezing. The root and color development are better at 18.3–21.1 °C. The plants will go to seeding before attaining marketable sizes at the temperature below 10 °C. The requirements are more or less the same as that of turnip and radish and need to be grown in nearly all types of soils but it thrives best on a fairly deep friable loam, moist but well-drained soil. The high yields have been obtained from deep rich alluvial soil such as silt loam. Heavy soils are not satisfactory because they produce asymmetrical roots in large quantities. It is very sensitive to acidic soil but thrives very well in alkaline soils with *p*H as high as 9–10.

Cultural requirements

During September-October, the seeds are sown in the plains whereas in the hills, it is March-May. The time of sowing of garden beet is slightly later than turnip or carrot. As a matter of fact all these root crops are sown at the same time during cool-weather. In some parts like Bengaluru it is sown in June-July also.

As other root crops it is also preferred to be sown on ridges with rows 30–45 cm apart and with plants about 15–22 cm apart. 25 tonne/ha of FYM is mixed thoroughly in the soil at the time of field preparation. 37.5 kg N, 100 kg P, 500 kg K/ha are applied to the soil before sowing. The furrows are irrigated 2 days before sowing. The seed is sown 1.5–2.5 cm deep and irrigated immediately after sowing in light soils. At some places the seeds are soaked for about 12 hours before sowing to facilitate better germination in the field. It requires 12–14 kg of seeds to sow one hectare of area.

Intercultural operations

These operations are more or less the same as that of radish and turnip. Care should be taken to see that the young seedlings after germination are

provided with proper spacing between the plants by thinning the excess seedlings. Clean, shallow cultivation is needed to control weeds. The crop should be topdressed with 37.5 kg N/ha 30 days after sowing. Ensure sufficient moisture in the root zone, especially during root enlargement stage. Shallow hoeing and earthing up are essential intercultural operations for good growth and shape of roots.

Pest and disease management

Diseases

***Cercospora leaf spot** (Cercospora* sp.*):* It is readily identified by small brownish spots with reddish purple borders which give the leaf a speckled appearance. As the disease advances the spots enlarge and turn grey. The spots usually appear on older leaves and the fungus does not attack the root of the plant. Spray carbendazim 50 WP (0.1%) for controlling cercospora leafspot. Practicing crop rotation also is beneficial.

Downy mildew: Spray carbendazim 50 WP (0.1%) for controlling the disease.

Bacterial blight: It is caused by *Pseudomonas syringe*. Its symptoms are numerous water soaked, dark brown irregular spots on leaves. Removal of infested plants is the only remedy known for the disease.

Insect pests

***Semi loopers** (Plusia* sp.*):* The green caterpillars damage the green foliage which may be controlled by spraying carbaryl (0.1%).

***Beet leaf miner** (Pegomyia* sp.*):* The larva is a white maggot about 0.8 cm long which burrows into the tissues of the leaves between the upper layers and cause serious injury, and thereby checking the growth of the plant. Destruction of the fallen leaves and spraying the ventral side of the leaves with phosphamidon (0.035%) or methyl demeton (0.03%) *is helpful in controlling the pest.*

***Web worms** (Loxostege* sp. *or Hymenia* sp.*):* They attack the beets by eating the leaves. The eggs are deposited on the leaves and the larvae attack the foliage either spinning small webs among the tender leaves or else feeding on the underside protected by a small web or with no protection. The pest can be controlled by spraying rogor @ 1 ml/l of water.

Harvesting and yield

Tubers are harvested after attaining a diameter of 3–5 cm. Harvesting is done 8–10 weeks after sowing by pulling out the plants along with the tuber. After uprooting, the roots are separated. The harvesting operation is the same as that of radish or turnip. Usually the top is removed for marketing the roots. On an average an yield of 250–300 q/ha can be obtained.

Roots can be stored for 2- 3 days under ordinary conditions and for longer period under cold storage conditions. At 0°C, with 95% relative humidity and at a freezing point of 29.5°C it can be stored up to two weeks.

Seed production

Cultural requirements for seed production are similar to that for vegetable

production. Plants require vernalization for induction of flowering and an altitude of over 1,000 m is congenial for seed production. Seeds are commonly produced by root-to-seed method or seed-to-seed method. In case of root-to-seed method, healthy and true to type stecklings are selected and stored for a short period for replanting.

Beet root and Swiss chard are wind-pollinated and are in the same species (*Betula vulgaris*). All varieties of beet root and Swiss chard will cross each other. Different varieties must be separated by up to 3–8 km for safe distance isolation. An isolation distance of 2,000 m and 1,000 m should be maintained for the foundation seed and certified seed production, respectively (Arya, 2003).

Let the seeds mature and dry on the stalk before harvesting. Fruits become brown on maturity. Plants are cut when the fruits on lower branches are mature. Then they are dried, threshed and seeds are separated and packed for storage. By gently rubbing the seeds off their stalks, the seeds can be separated. Each 'seed' is botanically a berry, and contains several actual seeds (breaking them apart would damage many of the seeds). This is why beets and chard often give up several plants in a spot despite the most carefully frugal sowing efforts. Beet root seeds remain viable for a fairly long period under room temperature. Beet root seeds will last for up to 5 years if properly stored. ●

CHAPTER 17

Bulb Crops

THE term "bulb" is used by most people to refer to plants that have underground, fleshy storage structures. Only some of the plants commonly called bulbs actually are bulbs. The definition of a bulb is any plant that stores its complete life-cycle in an underground storage structure. The primary function of these underground storage structures is to store nutrient reserves to ensure the plants' survival. Bulb crops include onion, garlic, leek, shallot and chive. All the bulb crops belong to the family Amaryllidaceae (formerly family Alliaceae). Alliaceae was formerly treated as a separate family. Allioideae is the botanical name of a monocot sub-family of flowering plants in the family Amaryllidaceae, order Asparagales., The sub-family name is derived from the generic name of the type genus, *Allium.* Most of them need similar climatic and soil requirements. They are grown in India as winter vegetables. In some regions with a moderate climate, onion can be grown in the rainy season as well. The cultural requirements of all crops belonging to this group are more or less similar.

ONION

Fig. 17. Onion

Onion is one of the oldest cultivated plant species. It probably originated in Middle Asia and the regions around the Mediterranean sea. It is reported to be a native of Asia perhaps from Palestine to India and might have originated from north-west India, Afghanistan, the Soviet Republics of Tajik and Uzbek and western Tien Shan (mountain ranges located in Central Asia). In India, it is grown from very ancient times as mentioned in the Charaka Samhita, a famous early medicinal treatise of India. In Hindi it is known as *Pyaz.*

Onion is one of the most important commercial vegetable crops.The major onion growing states are Maharasthra, Karnataka, Odisha, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Bihar and Gujarat. In India onion is grown in an area of 1087,000 ha with a production of 17511,000 tonne and productivity of 16.1

tonne/ha (NHB, 2011). The production and demand for onion are relatively high.

India is one of the exporters of onion. It is exported to Bangladesh, Malaysia, Sri Lanka, United Arab Emirates, Pakistan, Singapore, Philippines, Nepal, Oman, Mauritius, Saudi Arabia, Qatar, Bahrain, and others. Onion exports during 2009–10 was 16.65 lakh tonne valued at ₹ 2,319 lakh (NHB, 2011). Very small bulbs (2–3 cm diameter) with deep purple colour and high pungency are grown near Bengaluru in Kolar district of Karnataka for export to Malaysia and Hong Kong. Rose onion is export oriented crop. The international market demands export qualities like bulbs of uniform size, shape, weight, dark red shining uniform color, globe shape with 2.5–3 cm diameter. Based on the above requirement rose onion varieties have been developed.

Onion is a very common crop grown all over India and is consumed by every family either as raw in the salad form or as cooked along with spices and vegetables. Primarily, the bulb is used as a vegetable but in some places the green onions are also cooked. Sometimes, the flowering shoot known as scape is also used as vegetable. There are several local preparations of onion in different parts of the country.

Onion is rich in minerals like phosphorus and calcium and carbohydrates. It also contains protein and vitamin C. Ripe onions contain 85–90% water, 7–10% carbohydrates, 1–2% protein, 0.25% fat, 0.4% mineral matter, 0.18% calcium, 0.05% phosphorous, 0.7% iron, 120 IU vitamin B and 0.41% nicotinic acid. It has some useful medicinal properties also. White onions are grown in Tamil Nadu, especially for use in *sambar.*

Botany

Onion (*Allium cepa* L.; 2n = 16) belongs to the monocot family Amaryllidaceae and the sub-family Allioideae. Onion is a herbaceous annual for the edible bulb production and biennial for the seed production. The genus *Allium* contains about 300 widely distributed species. The edible portion is a modified stem known as bulb, which develops underground. Onion forms the bulb in the first year and the seed in the second year. The leaves arise from a shortened crown stem. The sheaths of the older or outermost leaves enclose the younger ones. The basal portion of the leaves encircles the stem, and thickens to form the bulb. The stem elongates during the second year forming the flower stalk. The onion has a fibrous root system extending to a depth of over one meter, but most of them are found in upper surface about 25 cm area. The typical flavour of onion is owing to the presence of a volatile oil known as allyl prophyl disulphide. The red or purple colour is because of the pigment anthocyanin and yellow colour is because of flavanols such as quercetin and its derivatives.

Floral biology and nature of pollination: It has bisexual flowers and is a highly cross-pollinated crop. Flowers are borne in simple umbels at the apex of a floral stem which is hollow and round in cross section and somewhat swollen at the middle or near the base. Most onion varieties produce seed stalks over one meter height. The number of seed stalks per plant may vary from 1 to 20 or more depending on the variety, size of mother bulb and time of plating. Before expanding, the umbel is enclosed within a papery spathe consisting of 2 or 3

bracts which are split open by the pressure of the developing flower buds. The number of flowers per umbel varies considerably, from 50 to over 2,000. The differentiation of the flower begins in the late winter. Temperatures around 20–22°C favour the vegetative growth while temperatures around 12–13°C are conducive to seed stalk formation. Also short-day conditions are favourable to seed production. White or bluish flowers have an outer and an inner whorl of stamens of three each. The anthers of inner stamens dehisce first. The pistil has a three celled ovary with two ovules in each. The style is about one mm in length when the flowers open first. It is not receptive until it elongates to a length of about 5 mm, which requires 1 or 2 days after all the anthers have dehisced. Opening of flowers usually continues for a period of two weeks or more and onion plant may be in bloom for over 30 days. The fruit is a 3 lobed, 3 celled capsule, each locule containing 1 or 2 black seeds at maturity.

Breeding

Onion has been grown in India for a long time and some of its derivatives are also available. Various useful strains are available in different growing areas of the country. At some places efforts were made to maintain and grow the useful indigenous strains. Some varieties were also introduced from other countries and few of them have proved to be promising and have been used for commercial production. Genetic studies on onion have reported for better keeping quality and for suitability to dehydration. Efforts have been made to study the genetics of various economic characters and to utilize the male sterile lines for the commercial hybrid seed production. In onion, breeding methods are mass selection, pedigree selection, back-cross method, hybridization. In the development of hybrid, there are male sterile lines, maintainer lines and pollinator lines. A hybrid cultivar will result from a male sterile line and a pollinator line. Although India is one of the leading producers, very few workers attempted to test different hybrid combinations for heterosis and combining ability. Male sterile lines are required for heterosis (Nath *et al.* 2002).

Male sterility form indigenous source was found in Nasik White Globe cultivar at IIHR. It was transferred to six different genotypes which are now being used for exploiting heterosis. The two promising hybrids are hybrid-1 (MS65xSI13-1-1-1) and hybrid-5 (MS48xSI4-1-1-1) which gave good bulb yield of 45.5 tonne/ha. Currently, National Research Centre for Onion and Garlic, at Rajagurur Nagar (Pune) is maintaining 437 lines of onion. Several Indian varieties, indigenous germplasm, and exotic varieties were tested for resistance to pests and diseases. The line IHR-56-1 was resistant to Purple blotch; Red Creole, Pusa Red, Pusa Ratnakar, Arka Kalyan, N-2-4-1 and a few are moderately resistant to purple blotch. Pusa Red, Rampur Local, Patna Red are tolerant and Telagi Red, White Large, Poona Red, Bellary Red, Patna Red, N-257-9-1, are found resistant to basal rot. Micropropagation of male sterile (CMS) plants of female parent can be useful in hybrid seed production. Haploids have been successfully produced from cross-pollinated ovules and their diploids will be useful for the development of inbred lines within a shorter time. Interspecific hybrids can be obtained by protoplast fusion. In monocotyledenous onion plant, transformation by

Agrobacterium rhizogenes has been successful (Arya, 2004).

Improved cultivars

Red onion cultivarss

Arka Kirthiman (F1): It is developed by IIHR, Bengaluru. An F1 hybrid between MS-65 and sel. 13-1-1 Hybrid. Medium sized bulbs with globe shape and firm texture, Bulbs red in colour with bulb weight 120–130 g, tolerant to purple blotch, basal rot and thrips, long storage (4–5 months). Suitable for *kharif* and *rabi* seasons. Duration 125 days. Yield 470 q/ha. Recommended for Karnataka.

Arka Lalima (F1): It is developed by IIHR, Bengaluru. An F_1, Hybrid between MS-48 and sel.14-1-1 (Hybrid–5). Medium sized bulbs with globe shape and firm texture. Bulbs red in colour with bulb weight 120–130 g. Tolerant to purple blotch, basal rot and thrips. Long storage (4–5 months) suitable for *kharif* and *rabi* seasons. Duration 130–140 days. Yield 500 q/ha. Recommended for Karnataka.

Arka Niketan: It is developed by IIHR, Bengaluru. Globe shaped medium large bulbs with an average weight 100–180 g. TSS 12–14%. Duration 145 days. Suitable for *rabi* season. Yield 370 q/ha. Recommended for Uttar Pradesh, Maharasthra, Madhya Pradesh, Karnataka.

Arka Kalyan: It is developed by IIHR, Bengaluru. Globe shaped bulbs with deep pink coloured outer scales, internal scales fleshy, succulent, concentric, high TSS (10.5- 12%), suitable for *kharif* season. Yield 470 q/ha. It takes 140 days from seed to bulb.

Arka Pragati: It is developed by IIHR, Bengaluru. Globe shaped, thin necked and deep pink bulb. It has fleshy scales with high pungency. TSS (10.5–12.5%). Yield 450 q/ha. Suitable for *kharif* and *rabi* seasons. It takes only 130 days from seed sowing to bulb harvesting.

Pusa Red: Developed by IARI, New Delhi. Medium sized, flattish round, light red coloured bulbs. Bulb weight 90 g, TSS 12–13%. Very good in storage. Maturity 140–145 days after transplanting. Yield 250–300 q/ha.

Pusa Madhvi: Developed by IARI, New Delhi. Light red, roundish flat bulbs. Bulb weight 90–100 g. TSS 11–12%. Good in storage. Maturity 130–135 days. Yield 300–350 q/ha.

Pusa Riddhi: This is released by IARI, New Delhi. single bulb weight ranges from 70 – 100 g, pungent and rich in antioxidant (quercetin 107.42 mg/100 g). Suitable for *kharif* and *rabi* seasons. Good for storage and export. Average yield 316 q/ha.

Pusa Ratnar: Developed by IARI, New Delhi. Roundish flat, deep red bulbs. Bulb weight 100–110 g. TSS 9–10%. Fair in storage. Maturity 125 days. Yield 300–400 q/ha.

Bhima Super: This variety is released by DOGR, Rajgurunagar. Suitable for *kharif* and late *kharif* cultivation in the states of Maharashtra, Karnataka, and Gujarat. Bulbs are compact single centered, medium red colour round bulbs with tapering neck. The TSS 10–11%. Average yield 260–280 q/ha in *kharif* and

400–450 q/ha in late *kharif* season. Early maturing in about 108 days after transplanting during *kharif* and 115–120 days during late *kharif* and *rabi*.

Bhima Red: This variety is released by DOGR, Rajgurunagar. It can be cultivated during *kharif* and late *kharif* in the states of Maharashtra, Karnataka, and Gujarat. It is more suitable for late *kharif* season. The bulbs possess attractive red colour, round shape with TSS 10.0 to 11.0% and with higher share of marketable bulbs. It gives a yield of 300–400 q/ha. It matures in 115–120 days during late *kharif* and *rabi* season after transplanting.

Bhima Raj: This variety is released by DOGR, Rajgurunagar. Bulbs are dark red in colour, oval shaped with single centre and thin neck. The TSS ranges from 10.0 to 11.0%. This variety is also suitable for *kharif* and late *kharif* season. It matures in 120–125 days after transplanting with absolutely no bolters in *rabi*. Average yield is 250–300 q/ha with high per cent of marketable bulbs. The highest yield potential is 400–450 q/ha during late *kharif.*

Bhima Kiran: This variety is released by DOGR, Rajgurunagar. Bulb attains immediate light red colour after harvest. Bulbs are oval to round in shape, have very less number of bolters and doubles in *rabi* (less than 5%), thin neck, TSS 12%, good keeping quality suitable for storage upto 5–6 months. Matures in 130 days after transplanting. The average marketable yield potential is upto 415 q/ha during *rabi* season with national average yield of 300 q/ha.

Bhima Shakti: This variety is released by DOGR, Rajgurunagar. Bulbs attains immediate attractive red colour after harvest. Shape is round.Very less number of bolters 2.15% & 0.36% and doubles 5.69% & 1.38% during late *kharif* and *rabi* season, respectively. TSS 11.8%. Small to medium neck thickness, uniform neck fall during *rabi* and more than 70% neck fall during late *kharif*, Very good storage life. Bulbs mature in 130 days after transplanting during late *kharif* and *rabi* season. It is tolerant to thrips. Marketable yield during late *kharif* is 459 q/ha and during *rabi* 427 q/ha in Maharashtra with national average yield of 292 q/ha during *rabi* season.

N-2-4-:This variety is released by Agriculture Department, M.S. Roundish flat, deep red coloured bulbs. Bulb weight 80 g. TSS 12%, good in storage. Maturity 130–140 days. Yield 200–250 q/ha.

N-53: This variety is released by Agriculture Department, M.S. It produces roundish flat, deep red coloured bulbs. Bulb weight 80 g. TSS 9–10%. Poor in storage. Suitable for *kharif* season. Maturity 100–110 days. Yield 150–200 q/ha.

Agrifound Light Red: This is developed by NHRDF, Nashik. Flattish round, light red coloured bulbs. Bulbs weigh 90 g. TSS 12%. Good in storage. Maturity 135–140 days. Yield 250–300 q/ha.

Agrifound Dark Red: This is developed by NHRDF, Nashik. Roundish flat, deep red coloured bulbs. Bulbs weight 80 g. TSS 9–10%. Poor in storage. Suitable for *kharif.* Maturity 95–110 days. Yield 150–200 q/ha.

Yellow onion cultivars

Early Grano: Large, globular, yellow bulbs, good for salad and for green onion purposes. Bulb weight 100–120 g. TSS 6–7%, very poor in storage. Maturity 95–110 days. Yield 400–500 q/ha.

Arka Sona: A high-yielding yellow onion variety developed by IIHR, Bengaluru, for export market. It has globe shaped, big sized bulbs (diameter 6.9 cm), bulb weight 140 g, TSS 10%, low pungency and uniform yellow color. It gives bulb yield 450 q/ha in 120 days.

Arka Pitamber: Developed by IIHR, Bengaluru. Bulbs uniform yellow medium sized (5.2–60 cm diameter) bulbs with globe shape and thin neck, Less pungent with 11% TSS and 9.81% total sugar. Tolerant to purple blotch, basal rot diseases and thrips. Suitable for export market. Suitable for *kharif* and *rabi* seasons. Duration 140 days. Yield 350 q/ha.

White onion cultivars

Pusa White Round: Developed by IARI, New Delhi. Roundish flat, white coloured bulbs. Bulb weight 90–95 g. TSS 12–13%, drying ratio 8:1. Suitable for dehydration and green onion purposes. Maturity 130–135 days. Yield 300–325 q/ha.

Pusa White Flat: Developed by IARI, New Delhi. Flattish round, white bulbs. Bulb weight 95–100 g. TSS 11–12%, drying ratio 9: 1. Suitable for dehydration purposes and also good for green onion purpose. Good in storage. Maturity 130–135 days. Yield 325–350 q/ha.

Bhima Shweta: This variety is released by DOGR, Rajgurunagar. Bulbs are attractive white in colour, round in shape, very less number of bolters and doubles less than 3% in *rabi* season, thin neck, TSS 11.5%, matures in 110–115 days after transplanting during *rabi*, medium in keeping quality upto 3 months during *rabi* season. Average marketable yield during *rabi* season is 359 q/ha with national average yield of 282 q/ha. It is tolerant to thrips.

Bhima Shubra: This variety is released by DOGR, Rajgurunagar. Bulbs are attractive white in colour, oval to round in shape bulb, have less number of bolters up to 6% during late *kharif* and no bolters during *kharif* and doubles less than 3% in late *kharif* and krarif season, thin neck, TSS 10.4% in *kharif* and 11.7% in late *kharif*, matures in 112 days after transplanting during *kharif* and 125 days in late *kharif*. bulbs can be stored for 2–3 months during late *kharif*. It has capacity to tolerate environmental fluctuation, hence can be cultivated in all the three seasons. Average marketable yield during *kharif* is 245 q/ha and during late *kharif* 389 q/ha can fill the gap for processing from October to February.

Phule Safed: This is released by MPKV, Rahuri. It is white coloured variety. Bulbs are globular in shape with TSS 13%. Suitable for dehydration. Average yield is 250–300 q/h. Storage life is 2–3 months. Recommended for late *kharif* and *rabi* season.

Agrifound White: This is developed by NHRDF, Nashik. The bulbs are globuler in shape with tight skin, silvery attractive white colour having 4–6 cm diameter. TSS is 14–15%, good in storage. Maturity in 115–120 days after planting. Average yield is 200–250 q/h. Good for dehydration and suitable for *kharif* and *rabi* season.

Rose onion cultivars

Arka Bindu (rose onion): It is developed by IIHR, Bengaluru. Bulbs small (2.5–3.5 cm diameter), deep red, highly pungent, flattish globe shape, high TSS

(14.16%) with high dry matter content. Suitable for export market. Duration 90–100 days. Yield 250 q/ha. Recommended for Karnataka.

Arka Vishwas: A high-yielding rose onion variety developed by IIHR, Bengaluru. for export market. It has bulbs with dark red color, flat globe shape, small size bulb diameter 4 cm, bulb weight 40 g, close neck 0.8 cm, TSS 16%, duration 115 days, splits and bolters less than 10%. It gives bulb yield 300 q/ha.

Agri found Rose (rose onion): Developed by NHRDF, Nashik. Bulbs are dark red, flat globe shape, uniform in size (3- 3.5cm), weight 30–40 g TSS (15–16%), short duration (90- 100 days).

Bengaluru Rose (rose onion): This is a local indigenous variety, characterized by pre-mature bolters and split bulbs, bulb colour deep dark red, flat shape, bulb size 2.5–3cm weighing 20–30 g. TSS (16- 18%), low to medium keeping quality, variation in bulb weight, colour and size, short duration (90–110 days).

Cultivars suitable for green onion

Pusa Soumya: This is a bunching onion variety released by IARI, New Delhi. It is suitable for round the year green onion production. The variety is least affected by pests and diseases.

Climate and soil

Onion is a biennial crop and takes two seasons to produce seeds. In the first year bulbs are formed and in the second year stalks develop and seed is produced. Generally, it can be grown under a wide range of climatic conditions and is best suited as a tropical crop. It does best where the season is mild without the extremes of heat or cold or excessive rainfall.

It requires cool-weather during its early development and during the early growth of the seed stalk, varieties bolt readily between 10 to 15°C. A moderately high temperature and a dry atmosphere favours the bulb maturity as well as seed production. It requires a temperature of 12.5–23.9 ºC before bulbing and for better bulb production it requires 15.6- 21.1 ºC for about 10 hours a day and about 70% relative humidity. Warm temperatures favour good development of bulbs.

In India, onion varieties grown in the plains are short day types (10–18 hours day length) and long day types (13 –14 hours day length) are grown on the hills. The plants are quite hardy and at the young stage and they can withstand freezing temperatures.

Onion can be grown on various types of soils but it grows best in light soils which may be sandy loam or silt loam. Heavy or clay soils should be avoided as they do not permit proper bulb development. The optimum *p*H range is between 5.8- 6.5. In preparing the land for onion the field is ploughed to a fine tilth by giving 3–4 ploughings. The ploughings may be shallow because the roots do not penetrate deep in the soil.

Cultural requirements

Sowing time: In the plains it is sown from September (in West Bengal) – mid December (in Madhya Pradesh), but usually it is sown in October-November. Planting earlier than recommended may produce premature bolting in the bulb

reducing the yield and quality of the bulb. Usually one crop is taken during winter but in Tamil Nadu, Maharashtra and Andhra Pradesh two crops are taken, but in areas near Bengaluru in Karnataka almost three crops are taken, namely, monsoon crop (June -October), winter crop (October-January) and summer crop (January - June). *Kharif* crop has become quite popular in northern Indian plains also. In hills, long-day varieties are grown during summer months.

Nursery raising and seed rate: Prepare 25 raised seed beds of 7.5 m long, 1.2 m wide and 15 cm high for raising seedlings sufficient for one hectare. Apply 5 baskets of farmyard manure and 1/2 kg 15:15:15 NPK mixture to each bed and mix them well in the soil. Sow the seeds thinly in 5- 7.5cm rows and covered with fine layer of soil and mulched with dry grass. Water sprinkling is done everyday till they germinate. The seedlings get ready for transplanting in about 6- 8 weeks. A seed rate of 8–10 kg/h is required. However, a seed rate 20–25 kg/ha is required for rose onion.

Land preparation and transplanting: In the well prepared land, prepare plots of 200 cm x150 cm and apply 50% N and the entire P and K before transplanting. The recommended dose of manure and fertilizers is, 25 tonne/ha of farmyard manure, and 125 kg N, 75 kg P, 125 kg K/ha. Healthy seedlings of 12–15 cm height are transplanted in the well prepared fields in rows spaced at 15–20 cm apart and plant to plant distance of 7–10 cm, depending upon the variety.

A spacing of 8 cm × 6 cm, i.e. 8 cm between rows and 6 cm between plants with in the rows is adopted for rose onion.

In some areas, growing onion by sets is popular, especially, for *kharif* season. It gives better plant stand and yields but takes longer duration of the crop. The sets are planted on ridges which are 30–45 cm apart and the distance between plants is 10–12 cm. The multiplier onions are vegetatively propagated by bulblets. About 1.5 tonne of bulblets are required for planting in one hectare.

Intercultural operations

Irrigate the field once in 4–6 days depending upon the soil and weather conditions. Onion being a shallow rooted crop, keep the field free from weeds particularly during the early stages of the crop. Onion is closely planted crop, which makes the manual weeding difficult. Chemical weedicides have been profitably used for the control of weeds. Basalin 1 litre a.i. per hectare as preemergent weedicide before transplanting was found to be effective. The remaining 50% N is applied as top dressing 30–40 days after transplanting.

Pest and disease management

Diseases

Purple blotch (*Alternaria* sp.)***:*** The disease is very serious and appears on the leaves, stems, bulbs and seed stalks as small, whitish, sunken lesions with purple center that rapidly enlarge. The leaves or seed stalks fall over gradually. The infection of bulbs occurs late in the season when the plants are nearly mature. For control, dry infected leaves may be clipped and sprayed with mancozeb 75 WP (0.2%) or copper oxychloride 50 WP (0.3%). Bulbs should be harvested carefully

to avoid injury.

Bottam rot or basal plate rot *(Fusarium oxysporum* Schlecht*):* This is a serious disease of bulb crop. Field symptoms usually do not appear until the soil has become warm. At first, there is a progressive yellowing and drying back from the tips of the leaves. Plants that are infected when young may continue to grow until harvest time. A semi-watery decay affecting the fresh scales from the base and progresses upward and with early infection decay may be almost complete by harvest time. The fungus is able to cause the disease at temperatures of 15–30 °C and above. As storage disease basal-rot is most active at or above room temperature. Use of healthy, disease-free planting material in disease-free plots is recommended. Spaying the crop with carbendazim (0.1%) or benornyl (0.1%).

Stemphylium leaf blight *(Stemphylium vesicarium):* This disease has become very serious like purple blotch and basal rot. It causes burning tips of young seedlings and brown streaks on leaves and also develops brown streaks and blight on flowering stalks due to which seed crop fails even to the extent of 100%. Spraying of mancozeb 75 WP (0.2%) gives effective control. This disease occurs in eastern and northern parts of the country.

Bacterial soft rot *(Erwinia carotovora):* It affects the bulbs in the field as well as in storage. The disease enters the bulbs through wounds. This disease can cause considerable loss in storage. The rot usually begins at the neck of the bulb. Later the bulb loosens its firmness and it gives offensive smell through the neck when squeezed. It occurs most frequently in humid-weather and specially, in those varieties that have heavy green necks and do not cure well. Thorough and rapid drying at harvest time is essential and all the bulbs showing damage either mechanical or by insect pests may be discarded before storing. Control measures include proper sanitation, curing of bulbs during storage and crop rotation with non-host crops.

Onion smut *(Racists urocystis cepulae F.):* Smut appears as elongated dark slightly thickened areas at the base of the seedling leaf as it emerges from the soil. As new leaves are formed they become infected, swollen and bent downward. Raised black lesions appear near the base of the scales on plants starting to bulb. The fungus becomes inactive in soil temperature of 26.7 °C and above. Most of the seedlings die within 3–5 days. The disease can be controlled by treating the seeds with captan 50 WP (0.2%).

Downy mildew *(Urocystis cepulae F.):* Smut appears as elongated dark slightly thickened areas at the base of the seedling leaf or seed stalk. Later the diseased portions become pale green, yellow and finally the leaves collapse. After a period of storage the infected bulbs become soft and shrivelled and the outer fleshy scale becomes partly or wholly amber in colour, wrinkled and watery. These bulbs must not be used for planting. However, the fungus in the bulbs can be destroyed by dry heating for four hours at 41°C. Regular spraying of metiram 50 WP (0.2%) at 10–12 days interval will control the disease.

Black mold *(Aspergillus niger):* It is a serious disease during bulb storage. Rapid and thorough curing, good ventilation and temperature just above 0 °C are important measures to control this disease.

Bacterial stalk rot *(Pseudomonas gladiola* pv *allicola):* Symptoms are, internal

brown discolouration and dry rotting in the basal portion of the inflorescence stalk. Inflorescence dries up and falls down. The disease infection can be reduced by soaking the bulbs in ceresan wet (2000 ppm), and Streptocyclin (200 ppm) for two hours.

Insect pests

Onion thrips *(Thrips* sp.*):* It is a small, yellow sucking insect which causes white blotches on the leaves resulting in the browning of the tips. It is most injurious during dry-weather and is seldom very destructive during rainy season. Dusts containing 3/4 of 1% rotenone have proved satisfactory for use on bunching onions where the fresh green tops bring a marked preference. Wherever possible preventive measures should be used to restrict the thrips population. The cutting and burning of grass and weeds in waste places will destroy alternate hosts. Spraying of insecticides like imidachoropid (0.03%), or acephate (0.15%) or fipronil (0.1%) at fortnightly intervals helps managing thrips. Soil application of phorate (2 kg a.i./ha) at 2, 6 and 10 weeks after transplanting also helps in controlling the sucking pests. Regular irrgation also helps in minimizing thrips infestation.

Onion maggot *(Hylemia* sp.*):* The maggot feeds upon onion plants of all ages from young seedlings to mature bulbs. They channel onion bulbs thus permitting bulb rotting organisms to enter. Where maggots are a problem, infected bulbs from storage-houses and packing sheds should be dumped to an isolated place and covered with at least 30 cm of soil in early spring before the adult emerges out. These burial places should then be dusted several times at 10 days intervals with 10% parathion to kill the adults, if any. Application of granular insecticides like phorate 1 kg, or carbofuron 0.3 kg, or carbaryl 0.5 kg, can control the pest effectively when broadcast before light irrigation.

Harvesting and yield

Harvesting depends on the purpose for which the crop is grown and the maturity will depend on the variety being used. The green onions are harvested by pulling out by hand when there is little bulb formation and good, tender vegetative growth. The bulb crop is ready for harvest in three to five months after transplanting. When the bulb is ready for harvesting, about 70% of the top shoots get dry and fall over even when part of the leaves are green. At this time the foliage should be trampled, i.e. 1–2 weeks before harvesting. At the time of harvesting the bulbs, it is necessary that the soil is loose which may be done by light irrigation some days earlier. The bulbs may be dug out by shovel or *khurpi*. After harvesting and field curing for drying of leaves, leaves are cut leaving 2.5cm at neck. The bulb yield varies from 350- 450 q/ha. In case of rose onion, the bulb yield varies from 200–250 q/ha.

If season is mild the bulb after harvesting is left in the field for curing which makes it firm and dry, where as in hot-weather the bulbs are removed to the shade for curing. It takes generally 6–8 days. Bulbs should be saved from rains and direct sunlight. Injured, rotten, diseased and thick-necked bulbs should be sorted out at the time of curing before storage.

Onions are stored in a well-ventilated place with lot of aeration and sunlight. Onion bulbs are packed in perforated gunny bags and stalked in vertical column, one above, the other. However, height of such vertical column should not exceed more than 5 feet and should have sufficient space all around and bottom.

Seed production

The cultural requirements for seed production are similar to that for bulb crop. Insect-pollinated onion family plants need up to 1,600–4,800 m for safe isolation. Closely planted groups of plants can be caged or bagged and then hand-pollinated. The minimum isolation distance recommended between different varieties is 1,000 m. Some authorities stipulate shorter distances than this for cultivars with the same bulb colour. In some countries there are declared zones in which only varieties of a specific bulb colour can be grown for seed.

Two methods of seed production, *viz.,* bulb-to-seed method and seed-to-seed method, are followed in onion seed production. The most commonly used method is the bulb-to-seed method.

Bulb-to-seed method

Production and storage of mother bulbs: For raising a crop for bulb production onion seeds are sown in nursery beds and seedlings are raised. Seed sowing is done in October-November. Seedlings are transplanted in the field and the bulb crop is raised and the bulbs are harvested.

Well matured bulbs should be harvested. Maturity is indicated by the tops drooping just above the bulb, while the leaves are still green. After harvesting, the bulbs should be trampled leaving a half inch neck. Before storage a thorough selection and curing of bulbs should be done. The time required for curing depends largely on weather conditions and may take 3–4 weeks.

The storage should be well-ventilated. The bulbs should be well matured, dried and cured before storage. The roots of the bulbs should be left intact after harvest. The storage temperature influence seed yield. Temperature ranging from 4.5°C to 14°C with an optimum of about 12°C is the best for storage of mother bulbs. Plants from such bulbs produce early and heavy yield than those grown from the bulbs which have been stored at higher or lower temperature.

Planting of mother bulbs: Planting of mother bulbs for seed production is done in October-November. The land should be prepared to a good tilth. One deep ploughing followed by three to four harrowings and land levelling is desirable.

Bulbs selected for replanting should be free from disease infection. Doubles and long thick necked bulbs are discarded and only true to type bulbs are selected. The seed yield is affected by the size of the bulb, the bigger is the bulb-size, the higher is the seed yield. Although the increase in weight and size of bulbs result in higher seed yield, very large size bulbs if used will need a very high seed rate. A bulb size of 2.5–3 cm diameter needs about 1,500 kg to plant one hectare of land. Therefore, for commercial seed production medium sized bulbs (2.5–3 cm dia.) may be used economically.

The selected bulbs are planted in well prepared field. The growing portion of

the bulb is cut to the extent of 1/4 to 1/3 for easy and quick sprouting of more growing buds. The lower portion of disc like stem and roots is used for planting. To avoid rotting due to fungal infection of bulbs in the field, carbendazim (0.1%) solution is used for dipping the bulbs before plating. Bulbs are planted 2- 3 cm deep in the soil at a distance of 30 cm × 30 cm.

A light irrigation is applied immediately after planting; the subsequent irrigation may be given at 7–10 days interval. Weeding and mulching should be done frequently to have a good crop. Discontinuing irrigation when the seeds reached the milk stage give high yields of good quality seeds.

Roguing: In order to detect and eliminate different plant-types, roguing should be started before the bulbs are harvested. It is easier to remove late maturing bulbs at this stage. After the bulbs are harvested they may carefully be rogued for colour and off-types.

Harvesting and seed yield: The seeds are harvested when the fruit opens and exposes the black seed. A field is considered ready to harvest when about 10% of the heads have black seeds exposed. At this stage practically all the seed is well matured to give a good germination. 2–3 pickings may be necessary to harvest the heads. The seed heads with a small portion of the stalk attached are cut with sharp knife. When cutting, the umbels are supported in the palm of the hand and held between fingers to avoid seed loss. Seed heads after harvest are thoroughly dried on canvas. Heads can be threshed when seeds separate easily from them. Much of seeds fall from capsules during drying. The remaining seed is removed by flailing. Under the humid conditions, seeds may be dried in sheds with air circulation. Frequent stirring may be needed when the seed is dried in shed. Since, natural seed drying often requires 2–3 weeks, seeds can be quickly dried using artificial dryers or dehydrators. Before storage, the seed must be dried to 6–8% moisture. A seed yield of 500–800 kg/ha can be obtained.

GARLIC

Fig. 18. Garlic

Garlic (*Allium sativum*) is said to be a native of Central Asia and Southern Europe especially the Mediterranean region. In Hindi it is known as *lahsun.* Garlic is one of the oldest known foods, seasonings and herbs. Garlic was traditionally thought to be a strength giving herb and was fed to slaves working on the Egyptian Pyramids. Greek and Roman athletes ate garlic before their contest. The largest producers of garlic include California, followed by Egypt, France, Italy, Spain, India, Pakistan and Thailand.

Garlic is grown throughout the plains of India. Madhya Pradesh is the largest producer of garlic, followed by Gujarat, Odisha and Rajasthan. Presently, the area under garlic in India is 145,000 ha with a production of 710,000 tonne and

the productivity is 4.9 tonne/ha (USDA, 2011).

Garlic is a bulbous rooted plant. The root is composed of bulbs with smaller sections. It is one of the most ancient herbs and consumed by ancient Greeks and Romans in large quantities. This little historic bulb with strong pungency, flavour, top healing powers and numerous health benefits, has been in use for over 5,000 years. Books may have been written and may still be written in appreciation of this essential ingredient in unlimited casseroles, curries, vegetarian and non-vegetarian dishes, and its healing powers in almost all types of ailments pertaining to the human body, all over the world. The aroma on the fingers be removed or reduced by toothpaste. It is almost indispensable in Mediterranean and Latin American cooking. In India it is used for many meat preparations and bland vegetables.

Over sixty compounds, in garlic have been identified. Garlic contains calcium, potassium, iron, magnesium, several vitamins B, vitamin C, sulphur, iodine, besides carbohydrates and protein. They may be helpful, singly or synergistically, for the therapeutic values. Allicin, a sulphur compound, is one of these and is believed to be responsible for the important functions like lowering of triglycerides and cholesterol in our body, thus reducing the risk of heart attack. Studies reveal that diverse range of phytochemicals in garlic contribute to its antibacterial, antiviral, and antifungal properties besides lowering of blood pressure and decreasing the risk of blood clotting. They also enhance our immune system to fight the cancer cells. Garlic ranks among the best sources of selenium, which has antioxidant properties for cancer. Garlic counters infections of nose, throat, chest, lowers blood sugar levels in diabetic patients. It has important medicinal values for digestive disorders, eye sore and ear ache.

Garlic is rich in protein, minerals like phosphorus, potash, calcium and magnesium and carbohydrates. It also contains fat, vitamin C and sulphur. Its edible portion contains 62.8% moisture, 6.3% protein, 0.7% fat, 1% mineral matter, 0.8% fibre, 29% carbohydrates, 0.03% calcium and 0.3% phosphorous (Bharadwaj, 2004).

Botany

Garlic (*Allium sativum* L.) belongs to the monocot family Amaryllidaceae and the sub-family Allioideae. It is a herbaceous annual for the bulb production and a biennial for the seed production. The edible underground stem is the composite bulb made up of numerous smaller bulbs known as ‘cloves’. If very small cloves are planted or if growing conditions are poor, a single small solid clove usually called a ‘round’ is produced. Rounds if planted under favourable conditions give rise to usual composite bulb. Garlic has flat, longitudinally folded leaf blades, diverging at widely spaced intervals from its false stem. The scape of garlic is smooth, round and solid for its entire length unlike onion which is hollow. Many cloves of garlic do not produce flower stalk or the inflorescence may be partially or not at all exerted, its bulbs forming a swelling somewhere within the false stem, a few centimeter above the bulb.

Garlic contains a colourless, odourless, water soluble amino acid (alliin) in uninjured garlic. On injury of the cell, enzyme alliinase changes alliin to allicin.

Allicin is the antibacterial substance of garlic and has typical odour of fresh garlic. It contains allyl radicle of disulphide.

It is a cross-pollinated crop usually propagated vegetatively by cloves. *Allium sativum* is a diplolid with chromosome number 2n=16. A good number of local strains are available in different regions of India. They vary in the number of cloves, which ranges from 16–50, and in the size of the bulbs. There is a very little variation in shape. Most of the strains have white colour, some have reddish tinge also. Though its production and consumption are high, no special effort has been made to improve upon these strains. Garlic improvement is possible by clonal selection and a few improved varieties are available.

Improved cultivars

Bhima Omkar: This variety is released by DOGR, Rajgurunagar. The bulbs of this variety are medium in size, compact and white in colour. 18–20 cloves per bulb. TSS is 41.2%. Leaves narrow with medium green colour. Yield 80–140 q/ha.

Yamuna Safed (G-1): This variety is released by NHRDF. Bulbs are compact having silvery white outer skin, with Flesh cream colour. Average diameter is 3.51cm with 28–30 cloves per bulb. Matures in 155–160 days. Tolerant to purple blotch and stemphyliurn diseases. Yield 150–175 q/ha.

Yamuna Safed-2 (G-50): This variety is released by NHRDF. Performing well in north and western India. Compact bulb having white, skin with creamy flesh. Average diameter is 3.41cm, with 19–21 cloves per bulb. Matures in 165–167 days. Tolerant to purple blotch and stemphylium diseases. Yield 150–200 q/ha with a drymatter percentage of 40–41. TSS 38–40%.

Yamuna Safed-4 (G-282): This variety is released by NHRDF. The leaves are wider than other varieties, bulbs creamy white and bigger sized, having 15–16 cloves/plant. TSS 39–43%. Suitable for export. Maturity 125–130 days. Yield 175–200 q/ha. It has a medium storability.

Agri-found White (G-41): This variety is released by NHRDF. Bulbs are compact, medium sized (3.45cm diameter), skin with creamy flesh. Number of cloves is 20–25 per bulb and matures in 160–165 days. It is tolerant to purple blotch and stemphylium diseases.

Agrifound Parvati (G 313): This variety is released by NHRDF. Bulbs are white with pinkish tinge. Tolerant to common diseases, medium storability. Recommended for growing in medium and mid hills of northern region.

Godavari (Selection 2): This variety is released by NHRDF. Medium size bulbs. Equatorial diameter 4.3 cm, Polar diameter 4.3 cm Average 24 cloves per bulb. Highly pungent. Ready for harvest 140- 145 days after sowing. Yield 100–105 q/ha.

Ooty 1: This variety is released by TNAU Horticultural Research Station, Ooty. It give an yield of 171 q/ha. The crop duration is 120–130 days. The bulb is big and dull white in colour and weighs 30–40 g each. Each bulb contains 20–25 cloves. The cloves have a flattening surface inside. It is moderately resistant to blast disease, resistant to thrips, and tip drying caused by foliage nematode.

Climate and soil

Higher yield and quality is obtained in a mild climate. Excessive hot and long days are not good for proper bulb formation. Therefore, the crop is usually planted in winter and harvested when the hot season sets in, i.e. Jan-March. Garlic plants respond to day-length and form bulbs under long-days, regardless of the size of the plant. Although garlic can be grown on wide range of soils, a well drained loamy soil, rich in organic matter is best. Under heavy soil conditions, the bulbs are deformed. In poorly drained soils the bulbs get discolored.

Cultural requirements

Planting time: Planting of garlic in the main season, i.e. April-June, yields better than the early or late sowings. Garlic is planted during August in Karnataka and Andhra Pradesh and November in the northern plains. In Nilgiris, it is planted during early May and October. On hills it is planted during March-April. In some localities the planting may be done twice (May and October) if the climatic conditions are favourable.

Planting material: Garlic is propagated by planting the cloves obtained by breaking apart the bulbs. The number of cloves per bulb varies from 5–30 with 12 cloves the normal number expected. Seed or clove garlic is often obtained from other garlic growers because it is a vegetatively propagated crop. Each clove will produce one plant with a single bulb. The garlic is propagated by cloves which are carefully detached from the composite bulbs at the time of planting. The seed rate varies from 500–700 kg/ha.

Land preparation and planting: Land should be thoroughly prepared by repeated ploughing and planking. Field is divided into small beds and channels for easy intercultural operations. 25 tonne/ha of well rotten farm-yard manure/ha is mixed well in the soil at the time of land preparation. Two days before planting apply 50 *g* N, 60 kg P and 60 kg K/ha as basal dose and mix it in soil. A planting distance of 15 cm × 10 cm is suitable for sowing garlic cloves.

While sowing, care should be taken that the pointed position is kept upward. The cloves are dibbled in an upright position at a spacing of 15 cm from row to row and 7–8 cm from plant to plant. There should be enough moisture in soil while planting, otherwise after planting irrigation should be given immediately. Diameter of bulbs should be 2.5cm and above and not less than 25 g in weight. For best yield cloves having diameter of 8–10 mm should be used for sowing. About 500–700 kg/ha of cloves are required.

Intercultural operations

Shallow cultivation is given between the rows to keep the soil around the plants weed free. Usually within 60 days two weedings are required. In medium type of soils, during winter months, irrigation at 15 days interval is sufficient. In warm-season it may be irrigated 10 days interval which may eventually come to weekly intervals. Irrigation should be stopped at bulb maturity stage. 50 kg N/ha is applied after one month of planting as a top dressing.

Pest and disease management

As in onion.

Harvesting and Yield

Garlic is usually ready for harvesting when the tops become partly dry and bend to the ground. The crop is ready to harvest in 170–180 days after planting. It can be harvested when the top turns yellowish or brownish and shows signs of drying up. The, bulbs are lifted windrowed gathering several rows into each window. Tops are placed over the bulbs to protect the bulbs from sun. If temperature is very high the bulbs are taken to shade for curing for about a week otherwise curing is done in field. Tops and roots are removed by hand leaving about 2 cm of root and 2.25 cm of top. Average yield is 80–100 q/ha.

Garlic must be graded for market. Diseased and damaged bulbs should be sorted out. Thoroughly cured bulbs keep fairly well in ordinary well ventilated room. The moisture loss in 5 months period, i.e. May to September may be about 25%. Storage of garlic in bundles with tops helps to reduce storage losses.

Seed production

The cultural practices followed for seed production are similar to that for bulb production. Garlic is normally propagated by cloves. The well grown, uniform sized composite bulbs of a particular variety are selected and the cloves are separated. Healthy and uniform cloves are selected and used for planting. However, it has been recommended that the cloves may be sown at 7.5–12.5 cm apart in rows which are spaced 40 cm apart. ●

CHAPTER 18

Tuber Crops

TUBER is a swollen, fleshy, usually underground stem or root of a plant, such as the potato and sweet potato. Tuber crops are starchy root crops. The primary function of these underground storage structures is to store nutrient reserves to ensure the plants' survival. Tuber crops include potato, sweet potato, cassava, colocasia, elephant foot yam, yams, yam bean, tania, Indian potato and ginger.

POTATO

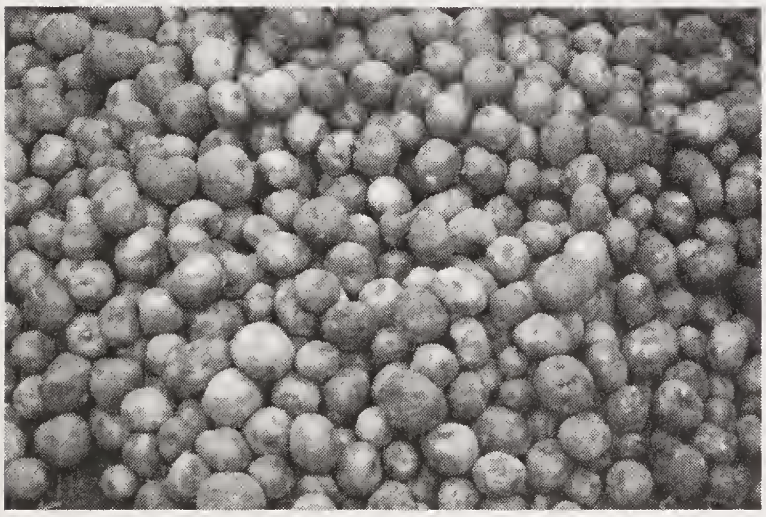

Fig. 19. Potato

According to the available linguistic evidence and archeological data, potato was an ancient cultivated crop at the time of discovery of South America. Since many wild species occur in South America especially in the Andes of Peru and Bolivia, it is believed that potato might have been originated from this region. From this area, it might have dispersed by many over a considerable area by the time Spaniards arrived in the 16th century. Evidences show that potato could have arrived in southern Spain in about 1570 AD from where it spread to other parts of Europe and the world. It was not grown as field crop in Europe until about the mid eighteenth century. In Europe, Irish were the first to recognize its great value for food. Ireland became completely dependent on potato by the end of eighteenth century, which is evidenced by the Irish famine of 1845–47 AD, also, which has occurred due to total loss of potato crop in Europe from late blight (*Phytophthora infestans*). Due to this famine, about one million lives were lost due to hunger in Ireland and at least similar number was migrated to America. By that time remaining parts of Europe were not as fully dependent upon potato as Ireland. In India, potato was introduced either by Portuguese or the Britishers. There are also some suggestions based on linguistic and botanical evidence that potato might have been introduced in India directly from South America across the Pacific Ocean. However, potato continued to be brought into India by British settlers and grown in the backyard of their residences. By 1675 AD, it seems to have established itself in the gardens of western India. By 1839 AD,

the potato cultivation had become well established as a profitable source of income to the needy population in the remote hill areas. By 1900 AD, small plots of potato were found near towns, scattered throughout India.

Potato is one of the most important food crops both in developed as well as in developing countries. It can be grown in wide range of climatic conditions and soil types with wide flexibility in planting and harvesting time. It can be harvested while tubers are still immature and also if the tubers are left unharvested for some time, they continue to increase in size and thereby improve yields. This flexibility makes this crop most suitable for inclusion in intensive cropping systems. In Hindi it is known as *aloo, alu.* In India potato is grown in an area of 1907,000 ha with a production of 414,83,000 t and a productivity of 21.8 tonne/ha (NHB, 2011).

Potato is a crop which has always been the "poor man's friend". Potato is being cultivated in India for the last 300 years. For vegetable purpose it has become one of the most popular crops in this country. Potatoes are also used for several industrial purposes such as for the production of starch and alcohol. As a food product itself, potatoes are converted into dried products such as potato-chips, sliced or shredded potatoes.

Potato is a nourishing and wholesome food. 100 g of potato (fresh weight) contains 16% carbohydrates, 2% crude protein, 0.1% fat, 1% minerals. 100 g of raw potato provides 80 kcal and boiled potato provide 69 kcal of energy per 100 g consumed. Potato protein has a very high biological value which is comparable with cow's milk. Potato has correct balance between the net protein calories and total calories. Fresh potato contains 20–30 mg of ascorbic acid per 100 g fresh weight. It contains 0.1 mg thiamin, 1.2 mg niacin, 0.25 mg pyridoxine, 0.3 mg pantothenic acid, 0.01 mg riboflavin and 14 mg folic acid per 100 g edible portion of freshly harvested potato. It also contains 40 mg phosphorus, 247 mg potassium, 21 mg magnesium and 11 mg sodium.

Botany

Potato (*Solanum tuberosum* L. ssp. *tuberosum*) belonging to the family Solanaceae is an annual, succulent, bushy, herbaceous, dicotyledonous plant. The tuber bearing *Solanum* falls into a polyploid series having a basic chromosome number of 12 and containing forms with 2n= 24, 36, 48, 60 and 72 (Peter, 1998). In plains (subtropical environment), the plant normally grows 0.4–1.0 m in height. In the hills (temperate environment), overall length of the stem may be well over 2.0 m. Here main stem acquires a sprawling habit with branches rising to a height of 1.0 m above the ground. The colour of foliage varies from light to dark green. In some varieties there is reddish purple pigmentation along the stem. The first leaf arising from the seed is usually simple. Later formed leaves are compound and occasionally bi-compound. It is pinnate with several pairs of leaflets (number varies with variety) along the rachis, which are more or less opposite. Every leaf has a terminal leaflet. Between successive pairs of lateral leaflets there are small folioles, which again usually arise in pairs. A pair of small leaf like structures, the stipules, is invariably present where base of the rachis meets the stem. Number, shape, appearance, colour and size of leaflets, folioles and leaves vary from variety to variety and is also influenced by environment. Numerous hairs cover the young

leaflets. Relatively fewer hairs occur on mature leaflets. Although stomata occur on both surfaces but they are more on the ventral side.

The roots are adventitious when grown from tubers. They arise at the base of the sprouts. Each sprout has its own independent root system. Root system is fibrous and well branched. Although roots may penetrate to a depth of more than a meter particularly in temperate regions when grown under rainfed condition, but bulk of the root is in the top layers (about 20–25 cm) of the soil.

The stem is of a branching type, the branches arise laterally along the whole length of stem. It attains a height of 0.3–1.5 m. Number of branches is a varietal characteristic and is influenced by environment, particularly light, temperature, day length and spacing. The stem may be erect and hard, firm and spreading or weak and flexible. The aerial stem may be solid or hollow (the terminal portion is always solid). In shape, the stem is more or less triangular with prominent wing-like growth along its two sides. The number of stems per plant and their thickness vary from variety to variety, state of sprouting at the time of planting and tuber size used for planting.

The stolon which is an underground stem arises laterally as an axillary bud on the underground portion of the stem. Stolons emerge within few days of plant emergence. Stolons usually grow along the horizontal plains in the ground. Sometimes stolons emerge above the ground and such aerial stolons acquire all the characteristics of a normal stem. Tubers are borne at the tip of stolons. There is no relationship between number of stolons with number of tubers and total tuber yield. Under temperate environment total number of stolons and their length is more as compared with sub-tropical environment.

Tuber forms when elongation of stolon ceases with lateral proliferation of the storage tissues. Morphologically tuber is fleshy stem with internodes. A tuber has two ends, *viz.* the rose (crown, apical bud) and heel (stem attachment, stolon) ends. Spaced on the surface of tuber are the eyes bearing the buds. Eyes are arranged in a spiral manner on the tuber. There are usually several buds in each eye. The shape of tuber varies from variety to variety. It may be round, oval, cylindrical, long cylindrical and even finger shaped. Skin surface is smooth or rough. The flesh of tuber has distinct region. The outer region is periderm, which is 7–15 cell deep. Next to periderm is cortex, forming the fleshy outer covering of the tuber. The inner core of the tuber is medulla. It forms two regions, an outer and an inner medulla can be distinguished. The inner medulla is not as rich in starch as the outer medulla or the cortex. Hence the inner medulla has somewhat light, water soaked appearance. The medulla forms a continuous connection with the eyes of the tubers. The sprout emerges from the bud on the eye of a tuber. Stolons and roots arise from the basal portion of the sprout. If sprout is damaged then new sprout arises from the eye. Sprouts are usually pigmented more so at the base, which help in identifying the varieties.

The flowers are borne on a stalk known as the floral axis. Posture of flower axis may be erect or droping. Potato flower is a complete flower. Five green sepals as well as five corollas are united. Petal colour is white, blue, red, purple or blue purple. The anthers are five in number, forming a close cone like structure around the ovary. Anther colour is green, lemon yellow, orange yellow or deep

orange yellow. Most of the varieties, under commercial cultivation, possess no pollen and are sterile. The pistils consist of two carpels which form a two loculed ovary with a single style and stigma. The ovary is very well developed. The stigma appears above the anther cone. Potato flowers produce no nectar and are not visited to any great extent by insects. After fertilization the ovary develops into a berry, the fruit. The berry is small, round, green or purplish green tinged with violet, about 2–4 cm in diameter. It is two celled and seeds are attached to the placenta and embedded in the green pulp of the fruit.

Breeding

The cultivated potato, *Solanum tuberosum* L., is a tetraploid (2n=4x=48). Potato is a long day plant for flowering and a photoperiod of 12–14 hours and temperature of 15–20°C favour flowering and berry setting. There are just a few genotypes which may flower under short day conditions of plains. Though both pollen and ovule sterility can occur, pollen sterility ranging from partial to complete absence of pollen grains is common in potato. About one third of the potato cultivars derived from *S. tuberosum* ssp. *tuberosum* do not form berries. Since potato is propagated vegetatively, it is highly heterozygous for all the characters. Parents for hybridization are selected on the basis of characters to be incorporated and then after hybridization seed is collected. Desired clones are selected from the progeny. Genetically distant crosses with wild species are avoided, as these result in progenies with wild characters which are difficult to eliminate. Gopal and Kumar (2003) have suggested the procedure for an early and safe elimination of unreproductive genotypes as under:

1. Seedlings of poor vigour may be rejected prior to transplanting in the field.
2. Clones with undesirable tuber colour, tuber shape, eye depth and tuber cracking may be rejected from the seedling stage onward.
3. No rejection should be done on the basis of tuber yield, average tuber weight or number of tubers in the seedling generation.
4. Negative selection (rejection of the poor phenotypes) for tuber yield and tuber weight can be initiated from the first clonal generation onwards. Whereas number of tubers can be considered for the rejection of undesirable types from second clonal generation onwards.
5. In the subsequent generations, for simultaneous improvement in tuber yield and its components, average tuber weight should be used as selection criteria after fixing a standard for the minimum number of tubers required in the selected types.
6. All later generations have to be tested in replicated trials at multi locations.

Potato is a vegetatively propagated crop. Clonal selection is effective in maintaining any desirable genotypes from selections made in the segregating progenies followed by hybridization which is between two selected individuals from genetically divergent sources. The breeding strategy followed in potato is through use of dihaploids obtained by pseudogamy in 4x cultivated potatoes. The dihaploids are crossed with diploid species that may be cultivated or wild for transgression of their useful genes like resistance to pests and diseases or for abiotic stresses. The dihaploids are maintained by vegetative propagation.

Improved cultivars

Pest and disease resistant cultivars

Kufri Himsona (F1): This is the first potato processing hybrid released by CPRI, Shimla, for cultivation in the hills of Himachal Pradesh. This variety contains more than 22% high dry matter and low sugars (less than 100 mg per 100 g of fresh weight). It produces excellent white chips on frying. This produces white, oval, shallow eyed tubers which have creamy flesh. It is highly resistant to late blight disease.

Kufri Sadabahar: This is a table variety of potato released by CPRI, Shimla. It produces more than 10% higher yield over Kufri Bahar. The variety produces white, oblong, shallow eyed tubers, having white flesh. It gives an yield of 350–400 q/ha. It has field resistance to late blight.

Kufri Frysona: This variety released by CPRI, Shimla, produces long shallow eyed tubers. It is resistant to late blight disease. It gives an yield of 250–300 q/ha, with more than 30–35 per cent French Fry grade tubers.

Kufri Swarna: Released by CPRI, Shimla. Medium-maturing, resistant to late blight and cyst nematode. Recommended for Nilgiri hills.

Kufri Giri raj: Released by CPRI, Shimla. Medium to late maturing and resistant to late blight. Recommended for North western hills.

Kufri Anand: Released by CPRI, Shimla. Medium maturing and resistant to late blight. Heavy yielder. Recommended for Northern plains.

Kufri Muthu: Released by CPRI, Shimla. Medium maturing and resistant to late blight. Recommended for Nilgiri hills

Kufri Kumar: Released by CPRI, Shimla. Late maturing and moderately resistant to late blight. Recommended for North Indian hills.

Kufri Kundan: Released by CPRI, Shimla. Medium maturing,moderately resistant to late blight and good keeping quality. Recommended for Himachal Pradesh and hills of Uttar Pradesh.

Kufri Neela: Released by CPRI, Shimla. Late maturing and moderately resistant to late blight. Recommended for Nilgiri Hills.

Kufri Chamatkar: Released by CPRI, Shimla. Late maturing and resistant to early blight.

Kufri Jyoti: Released by CPRI, Shimla. Medium maturing, good for processing, field resistant to late and early blights and immune to wart, and tolerant to viruses. It has wide adaptability.

Kufri Khasigaro: Released by CPRI, Shimla. Late maturing and resistant to both late and early blight. Recommended for Hills of Meghalaya.

Kufri Naveen: Released by CPRI, Shimla. Late maturing and resistant to late blight and immune to wart. Recommended for Northern hills of West Bengal and Meghalaya.

Kufri Neelamani: Released by CPRI, Shimla. Late maturing and resistant to late blight. Recommended for Nilgiri hills

Frost resistant cultivars

Kufri Sheetman: Released by CPRI, Shimla. Medium to late-maturing and resistant to frost. Recommended for North Indian plains and tarai area of Uttar

Pradesh. In north India, frost occurs every year during December and January in the plains of Punjab and eastern Uttar Pradesh.

Kufri Dewa: Released by Central Potato Research Institute (CPRI), Shimla. Medium maturing, good keeping quality and resistant to frost. Recommended for Tarai area of western Uttar Pradesh. In north India, frost occurs every year during December and January in the plains of Punjab and eastern Uttar Pradesh.

Heat resistant cultivar

Kufri Surya: This variety is resistant to heat and is released by CPRI, Shimla. Night temperature up to 18°C is ideal for cultivation of the ordinary potato varieties, but Kufri Surya could endure heat up to 22°C. Kufri Surya is the first of its kind in India.

Cultivars for chips making

Kufri Chipsona-1: Released by CPRI, Shimla. Medium-maturing and resistant to late blight. Excellent for chip making. Recommended for Indo-Gangetic plains.

Kufri Chipsona-2: Released by CPRI, Shimla. Medium maturing and resistant to late blight. Excellent for Chipping. Recommended for Indo-Gangetic plains.

Kufri Chipsona-3 (F_1): Released by CPRI, Shimla. A superior chipping hybrid, is an improvement over Kufri Chipsona 1 and 2. Its tubers have high dry-matter content of 22%. The hybrid is robust during storage and produces superior quality chips, i.e. crispy low oily chips.

Other cultivars

Kufri Himalini (F_1): Released by CPRI, Shimla. This hybrid has a maturity period of 110–120 days in also adapted to sub tropical plains. It provides a yield advantage of about 10% over Kufri Joythi and Kufri Giriraj in the plains and its keeping quality is better than all the cultivars developed so far for hill regions. It has been recommended for cultivation in Northwestern and North eastern hills of the country during summer season.

CO Simla potato: It is a selection from the hybrids obtained from CPRI, Simla and released by TNAU. It is suitable for cultivation in the plains during monsoon seasons. It gives an yield of 120 q/ha in 110 days. The tubers are medium in size.

Kufri Kisan: Released by CPRI, Shimla. Late maturing. Recommended for North Indian plains.

Kufri Kuber: Released by CPRI, Shimla. Medium maturing. Recommended for Bihar and Maharashtra.

Kufri Red: Released by CPRI, Shimla. Medium maturing and good keeping quality. Recommended for Plains of Bihar and West Bengal.

Kufri Safed: Released by CPRI, Shimla. Late maturing and good keeping quality. Recommended for North Indian Plains.

Kufri Sindhuri: Released by CPRI, Shimla. Late maturing, essentially short day adapted variety with red tuber. Heavy yielder even on low inputs. Recommended for North Indian plains.

Kufri Alankar: Released by CPRI, Shimla. Medium maturing. Recommended for North Indian plains

Kufri Chandramukhi: Released by CPRI, Shimla. Early maturing and good

for processing. Recommended for North Indian plains and plateau region of peninsular india.

Kufri Jeevan: Released by CPRI, Shimla. Late maturing. Recommended for Himachal Pradesh.

Climate and soil

Temperature and photoperiod have great role to play in raising a good potato crop. With increase in temperature as well as day length, assimilation allocated for haulm growth increases. When potato crop is grown in the hills during summer at a day length of 14–16 hours, plant may attain a height of more than one meter, whereas, same variety when grown in north Indian plains during winter the plant height may be around 60–70 cm. Even under short day conditions if minimum temperature is 22°C or higher, there is no tuberization. The ideal environment for potato production would be relatively higher temperature and long days early in the season to have enough haulm growth and then relatively lower temperature and short days to utilize the photosynthetic efficiency of haulms for the growth of tubers. For sprouting optimum temperature is 15°C and light is necessary to have thick, green, stout sprouts. Its growth is hampered with deviation from the optimum temperature for emergence at 20°C. However, this temperature is not available at planting time. At hills, soil temperature at planting is much lower than this and thus takes more time to emerge but % germination is higher. In plains, at planting, temperature is higher; therefore, presowing irrigation and organic mulching are beneficial for emergence. Minimum and optimum temperatures for leaf expansion are about 7 and 25°C, respectively. The optimum temperature for stem elongation and branch production is 25–30°C. Optimum temperature for photosynthesis is between 24–30°C. Cultural practices are so adjusted that tuber initiation and development coincides with period when night temperature is less than 20°C and day temperature is below 30°C.

Potato can be grown on all types of soils, however, very light soils (sandy) which have very low water holding capacity and heavy soils (clay) which are

Table 19: Optimum planting time for potato in different regions of India

Region		Planting time
A	Northwestern hills	May-June/Mid March-April/Feb-March
B	North Central high hills	Mid Feb-March
C	North Eastern high hills	
C1	-Darjeeling high hills	Mid March-Mid April
C2	-Shillong hills	Feb-March and September
D	Southern hills	August-September and Jan-Feb
E.	North Western plains	
E1	Punjab	Mid Sept-Oct and January
E2	-Jammu, Western UP, Haryana & Rajasthan	October
F	North Central plains	Mid October
G	North Eastern plains	
G1	-Bihar	Oct end-Mid November
G2	-West Bengal	Early November
G3	-Odisha	Early November
H	Plateau region	June-July and October-November

difficult to work with should be avoided. Potato need very high input and thus soils having the problems of salinity or acidity should be avoided. The ideal soil for this crop is one which is well drained, well aerated, deep and having a pH range of 5.2–6.4.

Cultural requirements

Planting time: Potato can be planted during March-April, August- December, January-February.

Optimum planting time for different regions of India is furnished in Table 19.

Planting material and seed rate: Potato is propagated from tubers which are commonly spoken as seeds. Tubers are planted either whole or cut into pieces. Certified seed should be preferred. The seed rate varies with the size of the tuber. It varies from 1000–2000 kg seed tubers per hectare.

Preparation of seed tubers: Where seed tubers are stored in cold storage, these should be taken out from the cold storage about 5–10 days before planting for sprouting. Optimum temperature for sprouting is 10–15°C. Since, ambient temperature at planting time in most of the places is more than 15°C, cooling is beneficial for sprouting. Light is most essential for sprout growth, therefore, arrangements for light may be made for all the 24 hours. In the absence of light, sprouts are etiolated, which come-off at the time of planting. Tubers with thick and stout sprouts at planting are quicker in emerging and have higher germination percentage. For sprouting, either spread seed tubers on the ground or keep them in trays, taking care that thickness of seed tubers is not more than 10–12 cm.

About 2000 kg of seed tubers of the size 30–50 g are needed to plant one hectare of potato crop. If seed tubers are of larger size then seed rate is increased. Seed size affects the initial vigour of the plants. Numbers of stems/hill have positive correlation with seed tuber size used for planting. Since mother tuber provides food for emerging stems, large size tubers increase the vigour of the plant. However, use of large size tubers increases the seed input and hence the cost of cultivation. Ideal temperature for emergence of seed tubers is 20°C. At places where soil temperature at emergence is more than 20°C, seed tubers up to the size of 100 g may be planted as whole; however, intra-row spacing is decreased. If seed tubers are of more than 100 g size then tubers may be cut for raising crop but planting is delayed for 10–15 days in the areas where soil temperature at planting is more than 20°C.

Cut tubers are planted when maximum temperature is not above 25°C. Under such circumstances presowing irrigation is beneficial. Care should be taken that every cut piece has at least two eyes. To save the cut tubers from fungal pathogens cut pieces should be dipped in 0.2% solution of mancozeb for 5–10 minutes and kept for 16–18 hours in a heap covered with gunny bags before planting into the field. Before placing cut tubers in a heap for curing, these are air dried. Ideal temperature for curing of tubers is around 20°C.

Land preparation and planting: Presowing irrigation will help in the preparation of field, decomposition of FYM and debris of previous crop and help in reducing the weed seeds. As weeds germinate with irrigation, germinating weeds will have to be ploughed. In addition, it enhances germination by making the

Table 20: Recommended fertilizer doses for different regions

Regions	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Alluvial soils of Indo-Gangetic plains	180–240	60–90	85–130
Hilly areas	100–150	100–180	50–100
Black soils of plateau	120–150	115	120
Acidic soils of southern plateau	120	115	120

moisture available to the emerging sprouts. Presowing irrigation also helps in regulating the soil temperature.

Selected field must have arrangement for drainage of excess water. Field should be deep ploughed at least twice, preferably with plough during May-June in plains to reduce the incidence of pests, diseases and weeds. Following rotation with non-solanaceous crops also helps in reducing the incidence of insect pests and diseases. Field must be leveled before planting of potato. Well rotten farm yard manure at the rate of 25 tonne/ha is incorporated at the time of field preparation. Apply 60 kg N. 100 kg P and 120 kg K as basal dose and top dressing of 60 kg N is recommended 30 days after planting. However, this varies from region to region (Table 20).

Spacing between rows is kept at 60 cm so that 20–25 cm thick ridge is made. Seed tubers of 20, 40, 70 and 100 g size are planted at intrarow spacing of 15, 20, 30 and 40 cm, respectively. Planting may be done manually or with automatic or semi-automatic planters. The criteria for working out the optimum planting time is that the maximum temperature should be less than 32 °C at planting, minimum temperature should become less than 20 °C by about 20–25 days after planting and available growing period should be more than 70 days so that economic yields could be obtained.

Potato is a high input crop and is generally grown during normal planting season. To catch the early market its planting is advanced by 15–25 days. Under such circumstances organic mulches (paddy straw, maize or bajra trash, rice husk or saw dust *etc.*) are spread to cover the ridges for lowering down the soil temperature. Mulches like paddy straw and maize or bajra trash may be removed during emergence or even 10–12 days after emergence. For early crop, potato varieties which give good yield at 75 days after planting are used.

Intercultural operations

Intercultural operations are done to remove weeds and to reduce the exposure of tubers. For best results, hoeing and weeding, and earthing up is done between 10–15 days after emergence. At this time, plants are 10–15 cm in height and most of the weeds emerge by this time. Further, there is minimum damage to crop. Intercultural operations at later stages may damage the crop also. Moreover, once the weeds are removed at this stage, the weeds which emerge at later stage are unable to compete with potato crop and thus cause negligible damage.

Weeds may be removed manually with spade or hand hoe or interculturing may be done with tractor drawn implements which are adjusted in such a way

that ridges remain intact. After interculture, field may be left for a day or two before doing earthing up of plants.

The balance nitrogen (60 kg N/ha) is top dressed 30 days after planting and earthing up of plants is done. However, this varies from region to region. In temperate climatic environment under irrigated conditions, where the growing season is of 4–5 months, three split doses of N (basal, first top dress, second top dress) are better than the two splits. Earthing up operation is done with spade or tractor drawn implements. The second earthing up is done 70 days after planting to cover up the tubers properly.

The potato being a shallow rooted crop needs irrigation at frequent intervals. The intervals are decreased when the tubers are formed.

Pest and disease management

Diseases

Viral diseases: Although more than 30 viruses infect potato only 6–7 viruses are important in India. These are PVX, PVS, PVA, PVY, PVM, PLRV. They produce varied symptoms individually and/or in various combinations, such as super mild, transient, typical green or yellow, mild or severe mosaics or mottle, general chlorosis of plants coupled with various types of foliage discolouration or distortion. While mosaics caused by different viruses are still important, leaf roll is no more a serious problem in India. Stem necrosis caused by a tospo virus is not transmitted through tubers and is a problem in early sown potato crop in some parts of central and western India. The best way to manage it is to delay planting and grow resistant varieties like Kufri Badshah. A new disease, potato apical leaf curl virus (PALCV), caused by a begomo virus has become a problem in seed crop in northwestern plains of the country.

Therefore, seed crop should be treated with imidacloprid @ 0.004% for 10 minutes before planting. In addition, crop may be sprayed with 0.002% of imidacloprid from emergence onward to check the population of white fly. Spread of contact viruses may be checked by minimizing the entry to the field while aphid transmitted viruses (PVA, PVM, PVY & PLRV) may be managed by dehaulming the seed crop when aphid population reaches 20 aphids/100 compound leaves.

Late blight *(Phytophthora infestans):* This is a most serious disease of potato. In hilly regions incased susceptibility of varieties results in losses as high as 85%. It appears every year on hills. However, in plains its intensity is low. In years with ample precipitation, it assumes epiphytotic proportions in plains also. On leaves it appears as pale green, irregular spots that enlarge into large water soaked tissue turning necrotic and dark brown or black. On lower side of leaves, white mildew (cottony growth) ring forms around the dead areas. On stem, light brown lesions develop which enlarge and encircle the stem. Tubers are also infected by rain borne spores from blighted foliage and act as the main source of primary inoculum.

Grow late blight resistant varieties, *e.g.,* Kufri Badshah, Kufri Jyoti, Kufri Sutlej, Kufri Jawahar, Kufri Anand, Kufri Chipsona- 1, Kufri Chipsona- 2, Kufri Pukhraj, Kufri Megha, Kufri Giriraj, Kufri Swarna and Kufri Kanchan. Use disease

free seed tubers and proper earthing up reduces the infection of tubers with the pathogen. Spray mancozeb (0.2%) as soon as weather conditions become congenial for late blight appearance (temperature 10–20°C, relative humidity >80%, intermittent rains, cloudy/foggy weather). Subsequent sprays of metalaxyl + mancozeb (0.25%) at 15 days interval may be given.

Early blight: The incidence of early blight is generally high in crops receiving imbalanced doses of NPK, particularly low doses of N. Early blight occurs in all potato growing areas but is more common in central India and plateau of Bihar, Jharkhand and Maharashtra. It also appears regularly in north-western and north-eastern hills and plains but is less significant. Leaf spot caused by *Phoma* spp., also occurs widely both in hills and plains and may cause significant yield losses.

For the management of early blight and phoma leaf spot disease free may be used tubers. Application of balanced dose of fertilizers, especially of N, 1.0% urea at 45 days and repeating after 10 days and spraying of mancozeb (0.2%), copper oxychloride (0.3%) and bordeaux mixture (1.0%) takes care of early blight and leaf spots. Solanaceous crop should not be grown in the nearby fields.

Bacterial wilt (Ralstonia solanacearum, Pseudomonas solanacearum): This is an important potato disease in north-eastern hills, eastern plains, north western mid hills (up to 2000 m), Deccan plateau and Nilgiris hills. It causes premature death of plants and rotting of tubers in transit and storage. In the field, yield losses may be upto 70%. Main symptoms are grey to brown milky slime exudation from vascular tissue of freshly cut stems and tubers and wilting of plants. It is both soil and tuber borne.

Healthy seed tubers are to be used for planting. Rotation of potato with crops like onion, garlic, cabbage, knol khol, cereals, horsegram, lupin is useful. Keeping the field fallow also helps in reducing its incidence. Application of stable bleaching powder @ 12 kg/ha as drenching along ridges will check the incidence.

Insect pests

Leaf hoppers: Species like *Alebroides nigroscutulatus.* Dist. and *Seriana equata* Singh. are vectors of purple top roll (PTR) and marginal flavescence (MF).

Jassids *(Empoasca devastans) and leaf hoppers (Amrasca beguttula):* They causes direct damage to potato crop by sucking up sap and are found in all potato growing regions. They cause serious damage to early planted potato crop in western Uttar Pradesh, Haryana and Punjab. It also causes severe damage to *kharif* crop in Karnataka.

White flies *(Bemisia tabaci):* and some other species are responsible for sucking sap. *Bemisia tabaci* is reported to be a vector of Gemini viruses also. White flies are serious pests for early potato crop in Punjab and Haryana.

Thrips (Thrips hawaiensis, T. Palmi, Megalurothrips destales and *Scirtothrips* sp.,*):* They suck the sap from plants. Thrips are also vectors of stem necrosis in potato.

Aphids *(Myzus persicae* (Sulzer) *and Aphis gossypii* Glover*):* Aphids are important pests of potato. Though their direct damage by sucking sap is marginal compared to other pests, they are vectors of various potato viruses and thus degenerate the seeds stock. *Myzus persicae* (Sulzer) and *Aphis gossypii* Glover

are the two most important vectors of potato viruses.

For all sucking pests, foliar spray of systemic insecticides such as dimethoate or thiometon or monocrotophos (0.03%) may be given.

Cut worms: The larvae (caterpillar) of cut worms damage the crop by cutting the young plants at the base and later on by feeding on shoots and leaves. They feed on tubers by making deep and irregular galleries. Deep ploughing during summer in plains and autumn in hills helps to reduce its population. Light traps installed in and around potato fields attract the adults of cut worms. Chloropyrifos 20 EC (0.05%) or carbaryl (0.2%) may be used for the control of cut worms.

White grubs: White grubs are distributed throughout the country. Grubs feed on rootlets, roots and tubers. Grubs damage the tubers without any symptoms on the foliage. In Shimla hills, yield losses to potato crop have been as high as 85%. Autumn ploughing in hilly areas exposes the grubs to adverse conditions and they also become prey to birds. The use of urea at higher doses kills the first instar grubs. Light traps can also be used for collecting beetle at night. Soil treatment with granules of phorate or carbofuran or isofenphos@ 2.0 kg a.i./ha at earthing up is recommended for the control of grubs.

Potato tuber moth: Potato tuber moth is a pest of potato both in fields and the country stores. The losses to potato in country stores may be even up to 70%. Prolonged dry and hot weather is quite conducive for potato tuber moth multiplication. Larvae of Potato tuber moth (PTM) damage the crop foliage, exposed tubers in the field and stored tubers in the country stores. In infested tubers, the feeding tunnels are packed with black excretory pellets and the larvae are inside the tunnels. Planting seed tubers at a depth of 10 cm as against 6 cm will reduce its damage. Proper ridging after 6 to 7 weeks of planting so that tubers are buried at least 25 cm below the surface avoids damage. Timely and adequate irrigations minimize soil cracking and thereby reduce the risk of tuber exposure to PTM. Harvested tubers must be removed from the field as early as possible. The crops like tomato, tobacco, chillies and brinjal may not be grown near potato fields. Sex pheromones can be used for mass trapping of males. Crop may be sprayed with either quinalphos 25 EC or monocrotophos EC (0.05%) alternately once or twice with bioagents like *Bacillus thuringiensis* (Bt) or Granulosis virus (GV).

Root knot nematode: Small galls are formed on potato roots resulting in size and number of tubers and thus the yield. Avoiding using of seeds from infested areas, deep plouging in summer months, burning of trash are the common cultural control measures. Following a two years rotational sequence of maize-wheat-potato- wheat reduces the root knot damage. Late planting of autumn crop and early planting of spring crop in north western plains reduces the nematode damage, while in hills early planting of summer crop in 4th week of march is ideal. Application of carborfuran @ 3 kg a.i/ha is required in two split doses, i.e. at planting and earthing up.

Harvesting and yield

The time of harvest is very important in potato. The development of tubers continues till vines die. Potatoes are harvested from the time they are of sufficient

size until the vines have fully ripened. The early maturing varieties can be harvested 80 days after planting and late varieties by 110–120 days after planting. Care should be taken at the time of harvest to save the tubers from injury.

If potatoes have been planted for early market, then harvesting is done when haulms are still green and tubers are immature. These tubers need immediate marketing. Since these tubers are immature, physiological weight loss is very high and tubers look shriveled within 2–3 days of harvesting. If crop is to be harvested after maturity then irrigation is withheld about 15 days before harvesting. It will harden the skin of potato tuber. Harvesting may be done by tractor drawn row potato digger or by bullock drawn 1 row digger or *Desi* plough or manually with the help of *khurpa* and spade.

If harvesting is to be done mechanically, then planting is to be done in such a way which facilitates mechanical harvesting also. After harvesting, cut, green and deformed tubers should be sorted out. Remaining tubers may be kept in a heap under a cool place for about 10–15 days for wound healing/curing. The height of heap should not be more than 1.0–1.5 m. Optimum temperature for curing of tubers is 20°C. Heap should be covered properly with thick layer of sugarcane trash or paddy straw or maize/bajra straw, to avoid greening of tubers.

Wound healing/curing has great bearing on losses during storage of potato. Potato has tender skin at harvest and some wounding invariably occurs. Wounds, if not properly healed, can result in excessive shrinkage and rotting during storage. Wound healing involves deposition of suberin (a waxy waterproof substance present in the cell walls of cork tissue in plants) and formation of wound periderms.

After curing tubers are graded as per need of the market. This produce can be stored in the cold stores at 2–3°C temperature and relative humidity at more than 90%. Potatoes are to be stored in cold storage to check losses due to transpiration, sprouting and rottage. Potato kept in cold storage at 2–3°C turn sweet (starch is converted to sugar). On an average 200–250 q/ha of tubers can be harvested.

Seed production

Since potato is propagated vegetatively and if viruses (PVX, PVS, PVA, PVY and PLRV *etc.*) are passed on to tubers and to successive generation, seed stock degenerates quickly if the same seed stock is used year after year. Virus infected tuber look almost similar to healthy ones but when planted give rise to weak and sick plants with symptoms like mosaic, rugosity, crinkling, necrosis, vein bending and rolling, etc. If care is not taken within 3- 4 generations the yield potential of seed may go down to 50%. Some viruses are transmitted by aphids (PVA, PVY and PLRV) while PVX and PVS are contact transmitted. Infection due to aphid transmitted viruses can be avoided/minimized by growing seed crop under low aphid period in plains, *i.e.,* October- December in Punjab and Haryana, Uttar Pradesh and parts of Bihar, Madhya Pradesh and Rajasthan and high hills above 2500 m in the northwestern Himalayan region, which are suitable for growing high quality seed potato. Fields infested with brown rot, common scab, nematodes (golden and root knot), wart and areas having high insect vector (aphid) problem during the crop season are not suitable for raising seed crop.

About 150 g of true potato seed (TPS) is required for raising seedlings in 75

m^2 nursery bed for transplanting one hectare of land. In our country TPS is suitable in the state of Maharashtra, Madhya Pradesh, Odisha, North-eastern Hills States, where yields are extremely low due to poor quality of seed tubers; and Gujarat, South Bihar and West Bengal, where seed tubers of desired quality cannot be produced and are procured regularly from northern part of the country.

True potato seed (TPS) is a sexually reproduced propagule in potato and results from the fertilization of ovules which develops into tiny seeds inside the fruit called berry. The seed thus called true potato seed (TPS) or botanical seed to distinguish it from the conventional tuber seed.

The following aspects are considered while raising a seed potato crop:

1. Certified or foundation seed should be obtained from a reliable source.
2. Crop rotation helps in reducing the incidence of some soil borne diseases such as black surf.
3. Slightly higher seed rate is used than the ware crop to have more stems per unit area and thus more number of medium sized tubers.
4. Maintain an isolation distance of 30 m between two varieties.
5. Nitrogen dose is reduced by about 20%.
6. Planting of well sprouted tubers is done by first week of October. Planting before October gives rise to plants which do not look quite normal due to high temperature and it will be difficult to rogue out the off type plants. Delay in planting will cut short the growing season.
7. Roguing out of virus affected plants may be done during the season at least 2–3 times. First roguing is done 25–30 days after planting and the second rouging, 15–20 days after first roguing. While roguing, touch only those plants which are to be removed. Tubers if any should also be taken out.
8. There should be minimum entry to the seed crop to avoid the spread of contact viruses. For this, complete earthing up is done at the time of planting and weeds are controlled by pre-emergence application of weedicides to avoid intercultural operations during the growing season.
9. Withhold irrigation 7–10 days earlier to dehaulming.
10. Only whole tubers are used for raising seed crop, as by cutting tubers, virus spreads through knife used for cutting of tubers.
11. Haulm killing is done by using gramoxone.
12. After harvesting, tubers are cured and treated with 0.25% emisan for 15–20 min for the control of black surf. If common scale is also a problem then treat the seed tubers with 3% boric acid for 30 min.
13. Treated tubers are stored in cold store and used for seed only.

SWEET POTATO

Sweet potato originated in Central America. It was introduced to India by the Portuguese travellers. However, South America has widely been recognized as the centre of origin of *Ipomoea batatas*. Tuber remains from a cave in Chilga region of Ethiopia's Northwestern highlands, Canyon caves in Peru dated between 8,000 and 10,000 BC has been reported. It is postulated that it might have been introduced probably from Ecuador or Colombia where types closely similar to sweet potato occur or from probably first introduced in Spain at least 60 years

Fig. 20. *Sakargandi*

before potato. Sweet potato might have been introduced in to India during the early sixteenth century by Portuguese. Almost in the same time, it reached China and became popular there after a great famine. Later it reached Japan and Okinawa. In Hindi it is known as *shakarkand.*

Sweet potato is grown in an area of 1,10,000 ha with a production of 10,73,000 tonne and a productivity of 9.8 tonne/ha. The major sweet potato growing states are, Odisha, West Bengal, Uttar Pradesh, Asom, Meghalaya and Madhya Pradesh (NHB, 2011).

Sweet potato is an important starchy food crop throughout the tropical and sub-tropical countries. Sweet potato tubers are usually consumed after baking, boiling, steaming, frying or candied into syrup or used as *puree*. Tubers are utilized for canning, flour making and are also important source of starch, glucose, pectin, sugar syrup and industrial alcohol.

Sweet potato contains more calories than even potatoes. Sweet potato is a rich source of vitamin A and also contains enough quantity of ascorbic acid, thiamine, riboflavin, niacin, phosphorus, iron and calcium (Ca). The 100 g edible root contains 68.5 g water, 1.8 g protein, 0.7 g fat, 27.9 g carbohydrates, 1.0 g fibre, 7700 IU vitamin A, 0.46 g vitamin B, 0.6 mg nicotinic acid, 0.93 mg pantothenic acid, 22 mg vitamin C, 40 mg vitamin E, 530 mg K, 30 mg Ca, 12 mg Mg, 0.7 mg Fe, 49 mg P, 15 mg S and 85 mg chloride.

Botany

Sweet potato, *Ipomoea batatas* L., belongs to the family Convolvulaceae, genus *Ipomoea.* It is an hexaploid having 90 chromosomes (2n=90). Most of the wild species of the section are 2x or 4x, although there are some species like *I. trifida*, which have 2x, 3x, 9x, 6x and 8x. It is a dicotyledonous perennial plant. Although the origin of *I. batatas* is not known, the species *I. trifida* is thought to be its nearest wild relative and its most probable ancestor. Sweet potato is a herbaceous perennial but cultivated as annual.

The stem is a branching vine with milky juice. Stems may be glabrous or pubescent when young, light green to purple in colour. The vine is prostate or ascending and twining. In normal clones, vine length is about 1.0 m, however, in some varieties; it may be as long as 6.0 m. Leaf shape varies from ovate to cordate, hastate or may be deeply lobed, entire or serrated. The surface of leaf is glabrous or with variable pubescence. The leaves vary in colour, usually green to purple. The petiole varies in length 3–10 cm and in some cases may be more than 25 cm. The seedlings have tap root with extensive root system in the early stage of development. When raised from vine cuttings, adventitious roots develop from nodes where the trailing stem comes in contact with moist soil. Generally, they grow laterally and grow to a depth of 50 cm. The tuber of sweet potato develops

by the process of secondary thickening of underground adventitious roots. The shape of the tubers is fusiform and globular with smooth or ridged surface. The skin colour may be white, yellow, yellow-reddish or purple. Flesh has white or different intensity of orange red. Intensity of flowering varies from clone to clone and some clones may not flower.

December to March is the best season for flowering and seed set in the southern peninsular region of India. The inflorescence is cyme which bears single or few flowers. The calyx is made up of five sepals and formed from the fusion of five petals and these persist on the capsule corolla is funnel shaped and formed from the fusion of five petals. It is attached to the base of corolla tube. Stamens are unequal in length. The pollen grains are globular and spinous. The pistil has two lobed stigma and the surface is covered with papillae. The ovary is superior, bicarpellary, two loculi and two ovules per loculus. The stigma is receptive very early in the morning hours and the pollination is entamophilous. The seeds are borne in capsule. A single capsule may contain up to four seeds but usually one or two develop. The seeds are albuminous, cotyledons folded, seed coat is hard and black in colour.

Breeding

Sweet potato is a vegetatively propagated crop. It does not produce flowers hence sexual reproduction is absent. However, sweet potato flowering can be induced by grafting it on certain related species of morning glory through which sexual reproduction and mass selection is possible. Important objectives for breeding of sweet potato should be high yield, better quality, photo insensitivity and resistance to pest and diseases, especially sweet potato weevil. The breeding methods adopted for improvement of sweet potato are clonal selection, mass selection, polycross, and pedigree method of selection in crossed progenies of selected clones. In sweet potato, spontaneous and induced mutations have also contributed to its variability besides natural cross pollination which has been utilized in breeding. Useful induced mutations can be selected and multiplied vegetatively as clones. The first and foremost method of breeding sweet potato is introduction. Germplasm is collected from different parts of the world and is evaluated under given environment and superior individuals are released for cultivation in the region. Most of the characters in sweet potato are quantitative with high heritability for several traits. To incorporate desirable character, hybridization is done between different varieties and species. After hybridization, plants are raised from hybrid seeds and individuals. Superior plants are selected and tested for desirable characters in the following 4–5 clonal generations.

Poor seed setting and shyness in flowering, presence of self and cross incompatibility are the major obstacles in sweet potato hybridization. There is also problem of cross-incompatibility. The flower opening starts in the early morning and dehiscence of anthers occurs before anthesis, therefore, for planned hybridization, the female flower is emasculated a day prior to anthesis. Emasculated flower buds as well as the intact flower buds of male parent are covered with butter paper bags. Pollinated flowers again covered with butter paper bags. After

4–5 days of pollination top cover of these bags are removed to allow aeration to the developing fruit. The mature seeds may be collected 25–30 days after pollination. The controlled pollination is generally done early in the morning, from 5.00 am to 8.00 am. Late pollination tends to reduce seed set. Selection can also be made from open pollinated populations. There is no control on male in this type of population. The seeds collected from female lines might be the product of natural selfing done by bees or the product of inferior or superior clones. Honey bees have a choice of visiting the same clone number of times and thus do a lot of selfing and thus introduce inbreeding depression in open pollinated populations. From open pollinated populations one cannot get a line with desired goals. Polycross and mass selection, is commonly used by the breeders.

Improved cultivars

Pusa Safed: This variety is released by Indian Agricultural Research Institute (IARI), New Delhi. This is a white skinned and white fleshed selection from China type FA-17-White. It bears elongated tubers that store well. The flesh after cooking becomes creamy white in colour, sweet and very palatable in taste. This variety has wide adaptability and performs well in states like Bihar, Uttar Pradesh, Tamil Nadu, etc. It matures in about 105–120 days and yields about 250- 300 q/ ha of tubers.

Pusa Sunheri: This variety is released by IARI, New Delhi. This is a selection from an American cross (Port Blanco × Worn Cap) and Australian Canner. It has elongated tubers with light brown skin and yellow flesh. Cooked flesh is orange or yellow, moist, sweet and palatable.

Kalmegh (BARI SP–7): Released by Tuber Crops Research Centre, BARI, Joydebpur, Gazipur, Bangladesh. This is an early maturing variety (about 90–105 days) of sweet potato. The tubers are round in shape and light brown in colour. The tuber yield is about 300–350 q/ha.

V-8: This is a selection from B-4004, an American type. It bears long luck spindle shaped, white skinned tubers with red or light purple streaks at both ends. The flesh is cream coloured. It is high yielding and early maturing variety. In India, it is grown in Punjab, Tamil Nadu and West Coast of India.

V-12: This is a Chinese type, also known as Treshina Tun. The tubers are large, elongated and white skinned with light purple shade towards the centre. It is grown in Tamil Nadu and West Coast of India.

V-35: This is also a Chinese type. The tubers are round light brown and are less affected by weevil. It matures in about 105–120 days and yields about 250–300 q/ha of tubers.

B.620: This variety is developed by Central Tuber Crops Research Institute (CTCRI), Thiruvanthapuram. It has long red tubers. Tubers are less affected by the weevil. It matures in about 120–135 days and yields about 220–250 q/ha.

H-41: This is a hybrid released by the CTCRI, Thiruvanthapuram. It is a cross between a Japanese variety Norin and a local strain. Plants are semi spreading. The tubers measuring 16 to 20 cm in length and 4.0 to 5.5 cm in diameter are red coloured, fusiform in shape and have white rind and flesh. The flesh tastes sweet,

boils easily and is largely free from fibre. The crop duration is 120 days and about 370 q/ha tuber yield has been recorded.

H.42: This is a hybrid reeleased by CTCRI, Thiruvanthapuram. It is a cross between an indigenous cultivar Vella Damph and an American variety Triumph. Plants are semi spreading with fusiform, medium long (14 to 20 cm) pink coloured tubers having yellowish white flesh. The flesh is sweet to taste and almost free of fibre. The tubers are very easy to boil. This hybrid has also shown field resistance to the weevil attack. It yields about 350 q/ha.

H.268: This variety has also been developed at the CTCRI, Thiruvanthapuram. It is a double hybrid developed by crossing two exotic and two indigenous cultivars. The plant is semi-spreading with a mean length of the shoot of 150 cm at the time of harvest with dark green leaves. Tubers are fusiform, with red skin and light yellow flesh. It is sweet after cooking and tolerant to weevil attack. The average tuber yield is 200 q/ha.

Gouri (H 85-16): A hybrid-cross released by RC CTCRI, Bhubaneshwar. Semispreading, skin is red and flesh is deep orange, rich in carotene. Duration 110–120 days.

Bhuban Sankar (H 85–70): A hybrid released by RC CTCRI, Bhubaneshwar. Semi-spreading, skin is red and flesh is white, good in culinary quality. Duration 120 days.

Rajendra Sakarkand-5: This is a hybrid released by RC RAU, Dholi. Rajendra Shakarkand-5 is spreading but not vigorous in growth. Leaves are green coloured, broad and have 4–6 lobes. The variety is drought hardy and responsive to fertilizers. It matures in about 105–120 days. Tubers are cylindrical with both skin as well as flesh white. The tubers are sweet in taste and contain about 28% dry matter. The tuber yield ranges from 250–300 q/ha.

Rajendra Sakarkand 35: This variety is released by RAU Centre, Dholi. Medium spreading having brown skin and white flesh. Duration 105–120 days.

Rajendra Sakarkand 43: This variety is released by RAU Centre, Dholi. Medium in maturity and spreading, both skin and flesh are white. Duration 110–120 days.

VL Sakarkand 6: Selection from exotic introduction of the USA; released by VPKAS, Almora. Tubers are elongated, skin colour is purple and flesh colour is light yellow. It is a spreading vine type having a duration of 120–135 days. The tubers have purple skin and light yellow flesh. Yield 200 q/ha. Released for general cultivation in Uttaranchal.

Samrat (S 30): This variety is released by the Andhra Pradesh Agricultural University, Hyderabad. Leaf is cordate, dark green with purplish veins, and succulent. It is moderately resistant to drought conditions. It is photo-insensitive type and hence can be cultivated successfully during *kharif* and summer seasons. Plant is medium in size, vigorous, fertilizer responsive, early maturing and a heavy yielder. Tubers can be harvested from tile 90th day onwards. Skin is white with pinkish streaks. Tubers are fusiform in shape and medium to big in size. They are sweet in taste, mealy and soft when cooked. They contain about 23.5% starch. The tuber yield varies greatly depending on season with maximum yield of 200-220 q/ha obtained in *rabi* season.

Kiran: This variety is released by APAU, Rajendranagar, Hyderabad. Spreading vines, tubers are bent at end, skin is red, flesh is orange and rich in carotene. Duration 110–120 days.

COCIP 1: This variety is released by TNAU, Coimbatore. Suited to September –October (Main), February – March and June-July planting with the short crop duration of 95–100 days. It yields 318 q/ha (tubers). It is adapted to entire Tamil Nadu. The tubers are tolerant to weevil incidence with better market appeal. The tubers have attractive pink skin with yellow flesh. Suitable for making cutlet, chips RTS beverage and mash.

CO 1: Developed by TNAU, Coimbatore. Tuber skin colour is light pink with white flesh. Field tolerant to sweet potato weevil. It yields 200–250 q/ha. Suitable for Tamil Nadu.

CO 2: Developed by TNAU, Coimbatore. A selection from open pollinated progeny. Yield 200–250 q/ha. Tubers are sweet with good cooking quality. Duration 110–115 days. Suitable for Tamil Nadu.

CO 3: Developed by TNAU, Coimbatore. A selection from open pollinated progeny. Tuber skin colour is light red and the flesh colour is dark orange. Rich in carotenes. Duration 105–115 days. Yield 200–280 q/ha. Suitable for Tamil Nadu.

Sree Nandini: Developed by CTCRI, Thiruvanthapuram. Early maturing, drought tolerant variety with 100 - 105 days duration and suited as catch crop in paddy fallows. Tubers are fusiform with light cream skin and white flesh. Highly tolerant to potato weevil. Excellent cooking quality. Suitable for Kerala. Yield 200–280 q/ha.

Sree Vardhini: Developed by CTCRI, Thiruvanthapuram. Early maturing, carotene rich variety for food and feed with a duration of 100 - 105 days. Tubers are somewhat rounded with pink skin and light orange flesh. Highly tolerant to sweet potato weevil and nematodes. It is a dual purpose variety; tubers for human consumption and vines for cattle consumption. Tubers have an excellent cooking quality.

Sree Bhadra: Early maturing, (90 days), trap crop for nematodes. Developed by CTCRI, Thiruvanthapuram.

Tubers have light pink skin and white flesh. Yield 200–250 q/ha. Suitable for U.P, Kerala, Maharashtra, M.P, Jharkhand and Bihar.

Sree Rethna: Early maturing, carotene rich orange fleshed variety with 90 - 105 days duration. It is rich in B carotenes (3200–3500 IU/100 g). This can be used as a trap crop against root knot nematodes. Developed by CTCRI, Thiruvanthapuram.

Sree Arun: Early maturing, (90 days), Developed by CTCRI, Thiruvanthapuram.

Sree Varun: highly palatable varieties. Developed by CTCRI, Thiruvanthapuram.

Sree Kanaka: Short duration (75 - 85 days) variety. The tubers have cream colored skin and dark orange coloured flesh with very high carotene content (8.8 - 10 mg/100 g). Yield 100–150 q/ha. It is suitable for *kharif* and *rabi*. Developed by CTCRI, Thiruvanthapuram.

Goutam: *I*t is a clonal selection after polycross. Round and ovate shaped tubers

with white skin and cream flesh. Maturity period 105–110 days. Yield 200–300 q/ha. Tolerant to sweet potato weevil

Sourin: Tubers are round and elliptic shaped with red skin and cream flesh. Yield 160–320 q/ha. Crop duration 105–110 days. Tolerant to sweet potato weevil

Kishan: It is also a clonal selection after polycross. Tubers are long elliptic shaped with purple skin and white flesh. Crop duration 110–120 days. Yield 170–260 q/ha. Tolerant to sweet potato weevil

Kanjanghad: This variety is released by KAU. It is obtained through selection and the duration of the crop is 105 - 120 days

Climate and soil

Sweet potato requires a warm humid tropical climate with a mean temperature of about 22 °C. Though sensitive to frost, it can also be grown in the hills up to an altitude of 1500–1800 m as a summer crop. Under rainfed conditions, the crop requires a fairly well distributed annual rainfall of 75–150 cm. Being a photosensitive crop, sunny days and cool nights are favourable for better tuber development. The crop thrives well under tropical conditions and the best growth takes place between 22–25°C temperatures.

The crop can be grown on a variety of soils having good drainage, but grows best in fertile sandy loam soils. Heavy clayey and very light sandy soils are not suitable for proper tuber development. Soil texture, drainage and aeration have great influence on growth and development of sweet potato. Sandy loam soils with clay subsoil are best suited for sweet potato production. Heavy clay soils which become hard after drying, check the growth and development of roots. Roots become rough, small, irregular in shape and stringy. These soils cause problems in harvesting also. In contrast, very light soils do hold enough moisture and nutrients for growth and produce long slender roots, which are not commercially desirable.

Cultural requirements

Planting time: Rainfed crop can be planted during June-July, and September-October. The irrigated crop can be planted during October-November (for uplands) and January- February (for low lands).

Planting material production: Sweet potato is propagated by means of vine cuttings. To obtain vine cuttings, raise nurseries from selected tubers. Eighty kg of medium sized weevil free tubers (each of 125–150 g) are required for planting in the primary nursery area (100 m^2 to plant one hectare). Plant the tubers at a spacing of 30–45 cm on ridges formed at 60 cm apart. Replant in the secondary nursery of about 500 m^2 area at a spacing of 25 cm on the ridges. Apply urea 15 days after planting at 1.5 kg/100 m^2 in the primary nursery. To ensure better plant growth in the secondary nursery, 5 kg of urea has to be applied in two split doses on 15^{th} and 30^{th} day after planting. Irrigate the nursery every alternate day during the first 10 days and once in 10 days, thereafter. Vines will be ready for planting on the 45th day.

Vines obtained from the freshly harvested crop are also planted in similar nursery area to obtain sufficient planting material. Cuttings obtained from the

apical and near apical portions of the vines are preferable for planting in the main field. Storing of cut sweet potato vines with intact leaves, in bundles covered with banana leaves (dipped in water) and kept under shade for two days prior to planting is recommended.

Land preparation and planting: Bring the soil to a fine tilth by ploughing or digging to a depth of 15–25 cm. Prepare ridges of 25–35 cm high, 60 cm apart for planting vines. Apply cattle manure or compost at 10 tonnes/ha at the time of preparation of ridges. The recommended N:P:K dosage for sweet potato is 75:50:75 kg/ha. Half the dose of N (38 kg) and full dose of P (50 kg) and K (75 kg) are applied as basal dose at the time of planting. Irrigate the furrows 2 days before planting.

Plant vine cuttings of 20–25 cm length on ridges at a spacing of 15–20 cm between the vines. The cuttings can also be planted on mounds taken at a spacing of 75 cm × 75 cm. On the top of each mound, 3–6 cuttings can be planted. Plant the vine cuttings with the middle portion buried deep in the soil and the two cut ends exposed to the surface. Ensure sufficient moisture in the soil for early establishment of the cutting. Provide adequate drainage and prevent waterlogging.

Intercultural operations

When grown as irrigated crop, provide irrigation once in 2 days for a period of 10 days after planting and thereafter once in 7–10 days. Stop irrigation 3 weeks before harvest. But one more irrigation may be given 2 days before harvest.

Weeding and earthing up operations are carried out about 2 weeks and 5 weeks after planting. The remaining quantity of N (38 kg) should be applied as top dressing 4–5 weeks after planting. Prevent development of small slender tubers at the nodes by turning the vines occasionally during active growth phase. Every node of sweet potato vine gives rooting when it comes in contact with moist soil. It is more a problem in medium to heavy soils than in light soils. Therefore, turning of vines will result in concentrations of tuberous roots at one place, which may improve the quality of produce. Turning of vines is normally done at 45 and 60 days after planting.

Pest and disease management

Diseases

Cercospora leaf spot: This may cause upto 20% losses. There are yellowish brown spots in the beginning, gradually turning deep brown with circular, irregular margin and measuring 1–9 mm in diameter. These spots form larger patches covering most portion of the leaf. It can effectively be controlled by spraying zineb 75 WP (0.25%) at 15 days interval (3 sprays) commencing from the first appearance of the disease.

Alternaria leaf spot: Leaf spots are found mostly on mature and old leaves. They are brown with concentric rings and well defined margins. As the spots become old, the infected tissue may crack and fall off. Humid weather is favouarble while dry weather results in bleaching of the lesions.

Helminthosperium leaf spot: There are small pale yellow under soaked lesions

on foliage which develop into brown necrotic spots 3–15 mm × 2.5–8 mm in size, surrounded by yellow halo. The matured spots are irregular, darker in colour and show a blighted appearance scattered over the leaves, petioles and vines. In severe cases, entire leaves dry up and the affected area in the field can be detected from a distance.

Feathery mottle potyvirus: This virus causes ring spot on the leaves and also pink band veining appears on the leaves. Infection spreads like mosaic and puckering occurs and the whole leaf becomes pinkish in colour. For viral diseases, using viral free planting material and removing and destroying the infected plants are the only control measures.

Chlorotic leaf distortion: It is caused by *Fusarium lateritium*. Symptons are: chlorosis on leaves, white powdery growth on leaf surface and margin and twisting and deforming leaves. It affects leaf opening. Spraying of carbendazim 50 WP (0.1%) once a month will control the disease.

Collar rot: The causal agent of collar rot is *Sclerotium rolfis* Sacci. The symptoms of the disease are sudden wilting of sprouts followed by rotting and death of the plant in patches. At first, small, oval straw or brown coloured lesions appear at the collar region or over the point where the sprouts emerge from the mother tuber. The lesions gradually enlarge and encircle the stem base and tissue becomes necrotic resulting in rotting of the sprouts. The plants easily break off. Drenching the soil around the plants with carboxin 50 WP (0.1%) is effective in controlling this disease. Crop rotation for three years also helps to a great extent.

Stem rot: Stem rot is caused by *Fusarium oxysporum* Schlecht var *batatas*. The first symptom is yellowing of old leaves at the bottom of the vine followed by yellowing of sprouts, falling off leaves, stunting and wilting. Use of resistant variety is the most effective control. Crop rotation also helps to reduce pathogen population. Seed tubers/vines for planting should be taken from healthy field. Dipping of tubers and vines in fungicidal solutions can help to reduce the incidence.

Storage rots: It is a major problem in temperate regions, where the tubers are stored for longer periods before use. On the other hand, in tropical region, the crop is grown and harvested throughout the year and therefore much of the produce is consumed soon after the harvest and very little is stored. The infected tubers quickly turn soft and moist and emit fermented smell. There are some varieties which are resistant to storage rot. To reduce intensity of the disease, careful handling of sweet potato tubers during harvest and transit is necessary so as to avoid unnecessary wounding, which otherwise would serve as site of infection for the pathogen.

Insect pests

Weevil *(Cylas formicarius* Fab*):* Among the insect pests infesting the sweet potato crop in India, the most destructive and wide spread one is the weevil (*Cylas formicarius* Fab). The weevil attacks the crop both in the field and during storage. The adult feeds on all parts of the plant (leaves, tender buds, stem roots and tubers), while larva bores into stem, root and tubers. In freshly planted vines, the weevil lays eggs in the collar or crown region near or just beneath the soil surface. The emerging grubs bore into the vine by tunneling. The adults get access to the

tubers through the cracks and crevices in the soil formed during tuber bulking. Eggs are laid in the periderm within the holes fed by the weevil. On emergence grubs feed inside the tuber in zig zag manner. A large number of grubs, pupae and adults are seen in the attacked tubers and the tuber is completely riddled and eaten away. Harvested tubers may contain different life stages of weevil and thus they continue the damage during storage. Weevil may also come from nearby fields to the stored tubers. Weevil can survive in the plant residues left in the field after harvest. Integrated approach adopting the following control measures are needed for effective control:

1. Field sanitation-remove and destroy the crop residues of the previous crop.
2. Use healthy and weevil free planting materials.
3. Trap adult weevils using sweet potato pieces (of about 6 cm diameter) of 100 g size, kept at 5 m apart during 50–80 days after planting at 10 days interval. Tubers may be cut and kept inside wire cages to avoid rat damage.

Vine borer *(Omphisa anastomosalis):* This is a minor pest and feeds on many species of *Ipomoea*. Its caterpillar tunnels the vines and makes them hollow. By constant feeding the vines are hollowed.

Leaf folder *(Brachmia convolvuli* Wals*):* The young larva of this insect feeds on the surface tissues of the leaves and shelter under thin webs. Older caterpillar spins webs by folding the leaves longitudinally and feed on the green tissues from within leaves. Caterpillar infestation can be controlled by spraying cabaryl (0.2%) or fenitrothion (0.025%).

Sphingidae caterpillar *(Herse convolvuli* Linn.*):* It is a polyphagous pest and attacks a number of plants including sweet potato, moong and urd. The pest is active during monsoon season. Carboryl (0.2%) or endosulfan (0.05%) has been found to control this pest.

Another polyphagous insect in Bihar is hairy caterpillar, which causes severe damage to the foliage. Endosulfan (0.05–0.07%), phosalone (0.06%) and quinalphos (0.05%) have been found to be very effective.

Brown hairy caterpillar (Euchromia polymena): *It* is a sporadic pest found defoliating the crop in many parts of India. It can be controlled by spraying fenitrothion (0.1%).

Beetles: Many species of metallic coloured tortoise beetles defoliate the crop. Grubs and adults of these beetles feed on sweet potato foliage. They can be controlled by spraying with monocrotophos (0.05%).

Bugs, thrips, aphids, jassids, mealy bugs, whiteflies and scale insects cause minor injury by sucking plant juice. Aphids, white flies and jassids, besides feeding the plant sap, transmit virus diseases in plants like internal cork and foliage aberration. Root mealy bug (*Geococcus coffeal* Gr) infests in groups on the crown region of roots and tubers, below soil surface. The infested plants loose the vigour. White grubs feed on the tuber by scraping the surface and making holes on the tubers.

Sweet potato weevil affects the tubers under storage conditions. Both adults and grubs cause damage to sweet potato tubers when stored. Only weevil free tubers should be selected for storing.

Harvesting and yield

Time of harvesting in sweet potato is influenced by varieties and environment. Sweet potato matures in 5–6 months in north India, while it takes only 4 months in south India. The maturity of the tubers is determined by cutting the tubers. Cut surface of immature tubers give a dark greenish colour while in mature tubers, the cut ends dry clearly.

The field may be irrigated 3–4 days prior to harvesting to facilitate lifting of tubers. After removing the vines the tubers are dug out. Care should be taken while harvesting to avoid mechanical injuries which would affect quality and storage life. Sweet potato tubers need to be cured before marketing and storage. In areas where sweet potato weevil is not a serious problem, the aerial parts are removed a week prior to harvest. This results in natural curing. Injury inflicted during harvest and handlings are cured by keeping tubers at 29°C and 85–90% relative humidity for 4–5 days. The yield varies with the variety, season of planting, soil types and management practices. In general, tuber yield varies from 200–250 q/ha.

Seed production

Normally, sweet potato is propagated through vine cuttings. Vines can be obtained from the previous crop or volunteers growing in the field where sweet potato was grown during last year or specially raised nursery for the purpose. Production of vines in nursery is described below:

Primary nursery: Nursery preparations are to be started three months prior to planting in the main field. For the production of nursery for one hectare, about 100 kg medium sized, weevil free seed tubers (125–150 g each) are planted in 100 m^2. Ridges and furrows are prepared at a spacing of 60 cm. Tubers are planted on ridges at a distance of 20 cm. Urea @ 1.5 kg/100 m^2 is top dressed after about 15 days of planting. Proper moisture is maintained throughout the growing season for the growth of vines.

Secondary nursery: After about 45 days of planting in primary nursery, vines are cut to a length of 20–30 cm for further multiplication in the secondary nursery and planted in an area of 500 m^2 for further multiplication. At the time of preparation of this area, 500 kg farmyard manure is added and mixed thoroughly. Ridges are made at a distance of 60 cm and vines obtained from primary nursery are planted on these ridges at a spacing of 20 cm. For better growth, 5 kg urea is applied in two splits at 15 and 30 days after planting. Field is irrigated as and when required to maintain proper moisture. Vines will be ready for planting in the main field in about 45 days. Recommended plant protection measures described for main crop should strictly be followed in the nursery area also.

CASSAVA

Cassava is native to South America; originated in Brazil and Paraguay. Today it has been given the status of a cultigen with no wild forms of this species being known. This species, native to the Amazon, Brazil, Colombia, Venezuela, Cuba, Puerto Rico, Haiti, the Dominican Republic, Honduras, and most of the West Indies, is now cultivated worldwide and has many names, including cassava, bitter-

cassava, manioc, tapioca plant. Tapioca is a starch extracted from the roots of cassava. In Hindi it is known as *tikhoor or Shimla aloo.*

Cassava is the third largest source of food carbohydrates in the tropics. Cassava is a major staple food in the developing world, providing a basic diet for millions of people. It is one of the most drought tolerant crops, capable of growing on marginal soils. Nigeria is the world's largest producer of cassava. Cassava root is a good source of carbohydrates, but a poor source of protein. A predominantly cassava root diet can cause protein energy malnutrition. In India, tapioca is grown in an area of 2,27,000 ha with a production of 87,47, 000 t and productivity of 38.5 tonnes/ha (NHB, 2011).

Tapioca is a staple food in some regions and is used worldwide as a thickening agent, mainly in foods. Tapioca is gluten free, and almost completely protein free. The plant has either red or green branches with blue spindles on them. The toxin found in the root of the red branched variant is less harmful to humans than the green branched variety. Therefore, while the root of the red/purple branched variant can be consumed directly, the root of the green branched variant requires treatment to remove the toxin. Commercially, the starch is processed into several forms: powder, fine or coarse flakes or meal, rectangular sticks, and spherical "pearls". Pearls are the most widely available shape; sizes range from about 1–8 mm in diameter, with 2–3 mm being the most common. Flakes, sticks, and pearls must be soaked well before cooking, to rehydrate them; they will easily absorb water equal to twice their volume, becoming leathery and swollen. All these products traditionally are white, but sticks and pearls may be coloured. In Indian cuisine, the granular preparation of cassava starch, also known as keera, is known as tapioca. It can also be used to thicken puddings. Tapioca is widely consumed in the state of Kerala. It is either boiled or cooked with spices. The roots of tapioca are used to prepare chips. Tapioca chips are also prepared in parts of South India. The cultivation of tapioca is manpower intensive only at the time of plantation and harvest. It provides a steady income to the farmers. Tapioca called *maravallikilangu* can be consumed raw (after removing the skin/outer cover). It can also be boiled and different dishes like *uppuma* (Tamil) can be made. It can also be made into chips to use as snacks during tea time. Tapioca is also referred to as "poor man's food".

Botany

Cassava (*Manihot esculenta*) belongs to the family Euphorbiaceae (spurge family) and the genus *Manihot.* It is a perennial woody shrub, grown as an annual. Cassava is a major source of low cost carbohydrates for populations in the humid tropics. Early literature on cassava described the genus with two edible species, *M. ultissima* and *M. aipi*, delineating species which have high and low cyanogenic glucoside concentrations respectively. More recently cassava was classified as all being the same species *M. esculenta.* It is the only one of 98 species in its family that is widely cultivated for food production. Cassava uniformly is 2n = 36. Other ploidy levels are not utilized, but have been produced experimentally. There are several closely related species found in the tropical and subtropical Americas that can be crossed with *M. esculenta.*

Cassava is classified as sweet or bitter. Like other roots and tubers, Cassava contains antinutrition factors and toxins. It must be properly prepared before consumption. Improper preparation of cassava can leave enough residual cyanide to cause acute cyanide intoxication and goiters, and may even cause ataxia or partial paralysis. Nevertheless, farmers often prefer the bitter varieties because they deter pests, animals, and thieves. The more-toxic varieties of cassava are a fall back resource (a "food security crop") in times of famine in some places.

Breeding

Extensive intervarietal hybridization between superior varieties, and selection among recombinants resulted in the isolation and release of many cassava high yielding varieties from CTCRI, Thiruvananthapuram, TNAU, Coimbatore and KAU, Thiruvananthapuram.

Improved cultivars

H-97: This is a hybrid between a local variety and a Brazilian selection. It has conical, short roots, yielding 250–350 q/ha, and has a crop duration of ten months. Developed by CTCRI, Thiruvananthapuram.

H-165: This is a hybrid between two local cultivars. The roots are relatively short and conical, yielding 330–380 q/ha. The variety is comparatively early maturing and can be harvested after 8–9 months. Developed by CTCRI, Thiruvananthapuram.

H-226: This is a hybrid between a local cultivar and the Malayan introduction, M4. The root yield is 300–350 q/ha, and crop duration is ten months. Both H-165 and H-226 are the predominant varieties cultivated in the states neighboring Kerala. H-226 has a high yield under irrigated cultivation in Tamil Nadu. Developed by CTCRI, Thiruvananthapuram.

Sree Visakham: This is a hybrid between a local cultivar and a Madagascar variety. It has compact roots, which have yellow flesh due to a high carotene content (466 IU/100 g). Crop duration is ten months, and the root yield is 350–380 q/ha. Developed by CTCRI, Thiruvananthapuram.

Sree Sahya: This is a multiple hybrid involving five parents, two of which are exotic and three indigenous. The roots are long-necked, yielding 350–400 q/ha. Crop duration is 10–11 months. Developed by CTCRI, Thiruvananthapuram.

Sree Prakash: This is an indigenous selection. The plants are relatively short with high leaf retention. Its crop duration is 7–8 months and its root yield 350–400 q/ha. Developed by CTCRI, Thiruvananthapuram.

Sree Jaya: This is a selection from indigenous germplasm. The plants are medium in height, yielding conical roots with white flesh. Its crop duration is six months and root yield 260–300 q/ha. Developed by CTCRI, Thiruvananthapuram.

Sree Vijaya: This is a selection from indigenous germplasm. It has conical roots with yellow flesh and a root yield of 250–280 q/ha. Crop duration is six months. Developed by CTCRI, Thiruvananthapuram.

Sree Harsha: This is the first triploid variety of cassava, released in 1996. It is a hybrid between a diploid selection and induced tetraploid of the released variety Sree Sahya. The plants are short, vigorous and non-branching or top-branching. The

leaves are broad, thick and dark green in color. Its roots are very compact, yielding 350–400 q/ha. Crop duration is ten months, but because of its early bulking nature it can be harvested as early as the 7th month without any yield loss or starch reduction in the roots. Sree Harsha has recorded the highest starch content of 39.1% among the released cassava varieties. Developed by CTCRI, Thiruvananthapuram.

MNGA-l: This variety is field tolerant to cassava mosaic disease. Released by CTCRI, Thiruvananthapuram.

Nidhi: This is a clonal selection suited to areas of sandy loam soils of central Kerala. Crop duration is six months and its mean yield is 250 q/ha. Developed by KAU, Thrissur.

KMC-1: This is a clonal selection suitable for intercropping in coconut gardens of central Kerala. Its crop duration is six months and its mean yield 305 q/ha. Developed by KAU, Trissur.

CO-1: This is a clonal selection from a local variety. Crop duration is 8–9 months and the mean yield is 300 q/ha. Developed by TNAU, Coimbatore.

CO-2: This is a clonal selection from an open-pollinated seedling progeny of a local type. It has compact roots. Crop duration is 8–9 months and its mean yield is 350 q/ha. Developed by TNAU, Coimbatore.

CO 3: This clone is released by TNAU. The plants exhibit branching habit. Since the plants are heavily branching, periodical removal of sprouts is necessary. It yields an average of 426 q/ha of tubers under irrigated and 273 q/ha of tubers under rainfed conditions, respectively. It is suitable for cultivation both under irrigated and rainfed conditions. It produces 8–10 tubers per plant. The tubers have dark brown skin with yellowish white rind and white flesh and contain a high starch of 35.6%. The tubers taste sweet with a low HCN content of 77.89 μg/g. The plants exhibit field tolerance to cassava mosaic virus. The crop duration is 8 months.

CO (TP) 4: This clone is released by TNAU. It is a high-yielding clone with duration of 8.5 months. This clone recorded a mean tuber yield of 506 q/ha. This culture is suitable for cultivation under irrigated as well as rainfed conditions during June-July and October –November, respectively. This clone is adapted to the districts of Salem, Namakkal, Dharmapuri, Erode, Coimbatore, South Arcot, Kanyakumari and Tirunelvali. The tubers are long cylindrical with brown skin and white flesh. The tubers are rich in extractable starch (40.0%), total sugars (5.60 mg/100 g) and with low HCN content in flesh (38 mg/g). This clone is moderately susceptible to Indian Cassava Mosaic Virus (ICMV) and the incidence of scale insects and spiraling white flies is low. This clone is highly suitable for starch and sago industries, because of its high starch content.

CO (TP) 5: This clone is released by TNAU, Coimbatore. It is resistant to cassava mosaic disease with fairly good starch content (28%). It is a moderate tuber yielder (380 q/ha). Plants are erect and top branching habit with regular flowering and seed setting. Tubers long, cylindrical, white flesh easy palatability and low in cyanoglucoside content. This can be planted during June – July; October – November. The duration of crop is 270 – 300 days.

MVD-1: This is a clonal selection exhibiting field tolerance to CMD. Crop duration is nine months and mean yield is 345 q/ha. Developed by Department of

Horticulture, Tamil Nadu.

Climate and soil

It thrives best in tropical, warm humid climate with well distributed rainfall of over 100 cm per annum. This crop can be cultivated upto an elevation of 1000 m. Planting can be taken throughout the year under irrigated condition and during April-June for rainfed crop. Any well drained soil preferably red lateritic loam with a pH range of 5.5–7.0 is best suited for tapioca cultivation.

Cultural requirements

Planting time: The main planting seasons are April-May with the onset of southwest monsoon and September-October with the onset of northeast monsoon. Planting can also be done during February-April, provided sufficient moisture is made available through irrigation. For maximum tuber production, April-May planting is preferred because the crop can effectively utilize both the monsoons. The second best season is September-October.

Planting material: Tapioca is propagated from cuttings. Select healthy mosaic free, vigorous plants for taking planting materials. Select mature healthy stems free from diseases or pests. About 2000 stems are required for planting one hectare. Harvested stems are to be stored vertically in shaded and well aerated places. Spraying dimethoate (0.05%) on the stem will control scale insects. Discard about 10 cm from the lower mature and about 30 cm from the upper immature end. Stems should be cut into setts of 15–20 cm length with 8–10 nodes using a sharp knife. Avoid mechanical damage while preparation and handling of setts. The cut end should be uniform. Dip the setts in carbendazim @1 g/l of water for 15 minutes before planting. For rainfed conditions, treat the setts with a mixture of potassium chloride @ 5 g/l of water and micronutrients, *viz.* $ZnSO_4$ and $FeSO_4$ each @ 0.5% for 20 minutes. Dip the setts for 20 minutes in *Azospirillum* and phosphobacterium each at 30 g/l.

Land preparation and planting: Before planting, plough the field 2–3 times or dig to a depth 25–30 cm depending upon soil type to establish a deep porous field in which the setts are to be planted. At the time of land preparation apply 25 tonnes/ha of FYM and incorporate into the soil. Form ridges and furrows at a spacing of 60 or 75 or 90 cm. The spacing for irrigated crop can be 75 cm × 75 cm (17,777 setts) and 90 cm × 90 cm (12,345 setts); for rainfed crop the spacing can be 60 cm × 60 cm (27,777 setts). Apply 50 kg N, 100 kg P and 50 kg K/ha as basal dose just before planting and mix with soil. Irrigate the furrows 2 days before planting. Plant the setts vertically with buds pointing upward on the sides of ridges following the spacings suggested above.

Intercultural operations

Keep the field free of weeds and maintain soil loose by 2–3 shallow diggings or hoeing up to 90 days after planting followed by light earthing up. Subsequent weedings should be done once in a month up to 5 months depending upon the weed intensity.

Under conditions of well distributed rainfall, cassava grows well as a rainfed

crop and irrigation is not necessary. However, the crop has to be irrigated to provide sufficient moisture under conditions of prolonged dry periods after planting. When the crop is grown under irrigation, yield increase of 150–200% over the rainfed crop has been observed. First irrigation is given at the time of planting. Life irrigation is given on the 3rd day of planting, followed by once in 7–10 days up to 3rd month and once in 20–30 days up to 8th month.

Fill up the gaps within 20 days of planting. Retain two shoots on each plant in opposite directions and remove excess shoots about 30 days after planting. Apply 50 kg N and 50 kg K/ha as top dressing 45 day after planting and mix with soil while earthing up the plants.

Pest and disease management

Diseases

Cassava mosaic disease (CMD): The disease is transmitted by a white fly (*Bemisia* sp.). As a rule, only stem cuttings from disease free plants should be used for planting to minimize the spread of the virus disease. For this purpose, tagging of disease free healthy plants for selection as planting materials must be practiced from September to December. All plants showing even very mild symptoms must be rejected. Mosaic tolerant varieties such as H-97 may be used to minimize economic loss of tubers.

Cercospora Leaf spot: *Cercospora* leaf spot can be controlled by spraying mancozeb 75 WP (0.2%) twice at 15 days interval.

Tuber rot: Avoid water stagnation. Give good drainage facilities. Spot drenching with copper oxychloride 50 WP (0.2%).

Insect pests

Red spider mites and scale insects: Red spider mites in the field and scale insects under storage are important pests of tapioca. Under field conditions light infestation of mites can be controlled effectively by spraying the crop with water at 10 days interval from the onset of mite infestation. In the case of very severe infestation, the crop can be protected by spraying 0.05% dimethoate or methyl demeton at monthly intervals from the time of appearance of mites. The stem may be sprayed with 0.05% dimethoate before storing as a prophylactic measure against the scales.

White fly (Bemisia tabaci): Integrated pest management practices: Remove alternate weed hosts, viz. *Abutilon indicum.*: Install yellow sticky traps @ 12/ha.; Use nitrogen judiciously; Avoid excessive irrigation.; Spray neem oil 3% or methyl demeton 25 EC @ 2 ml/l. While using neem oil, teepol should be added @ 1 ml/l for better contact with foliage.

Spiralling white fly: Grow resistant genotypes.; Install sticky cum light trap and operate between 4–6 a.m to attract the adult.; Spray dichlorvos 76 WSC @ 1 ml/l or triazophos 40 EC 2 ml/l. Add wetting agent.

Harvesting and yield

Crop can be harvested at 9–11 months after planting. During tuber maturity,

the leaves become yellow and 50% of leaves become dried and shed off. The soil near the stem base of the stem shows cracking. Tubers can be uprooted by using fork or crow bar. Under irrigated condition an yield of 400 – 500 q/ha and under rainfed condition an yield of 200 – 250 q/ha can be obtained.

Seed production

Ensuring self sufficiency in quality cassava planting materials vegetative propagation through cuttings is the method used for multiplication of improved cassava planting materials. However, the rate of multiplication is low. Rapid multiplication technology has been developed to increase the rate of multiplication (John Wambua *et al.* 2010).

1. The procedures for preparing cuttings involve preparation of the mini stem cuttings
2. The stem is cut into several small pieces
3. Each piece should have more than one nodes, depending on the portion of the stem from which it is cut
4. Pieces cut from the bottom of the stem (hardwood) may have 1 or 2 nodes
5. Those from the middle of the stem (semimature) may have 4–6 nodes
6. Cuttings from the tip portion (top green and tender) may have 6–10 nodes
7. The hardwood and the semimature cuttings are prepared using sharp tools such as shears, secateurs, or a handsaws
8. Cuttings from the top portion are prepared using the secateurs or sharp knives

Two methods for establishing rapid multiplication are described below:

Method 1

1. Research has resulted in improvement in cassava seed multiplication method called multicompartment tray
2. The tray compartments are filled with loamy soil, which is well moistened and then the cuttings are stuck each per compartment with the bud pointing upwards
3. The trays are kept under shade with sunshine penetration until the plants have sprouted and ready for transplanting
4. The trays can be put in a simple dome shaped polythene covered structure to enhance sprouting

Method 2

1. The other method for seed multiplication is through nursery seedbed
2. This method is good for cuttings from the middle and top parts of the stem (semimatured and top green)
3. The cuttings should be 7–10 cm long and planted vertically at a spacing of 10 cm × 10 cm in the nursery bed with two-thirds of each cutting buried in soil
4. The oldest end of the cuttings are the ones to be buried
5. It is then watered regularly to ensure that the cuttings do not dry

Black potted bags with soil method uses similar procedures of soiling and

handling as the tray method

1. The cassava plants are watered adequately to ensure fast growth and after 4–6 weeks, they are transplanted to field either to be irrigated or immediately after onset of rains
2. Clear polythene bags without soil method is another option
3. Cutting nursed for 4–6 weeks in polythene bags without soil, thus providing a quicker, less expensive and more convenient method

Handling and transportation of planting cuttings from source to distant field is very important in order to preserve the integrity of the stems. Quite often the buds break off easily when cuttings rub on each other resulting in poor germination

COLOCASIA

Fig. 20a. Colocasia

Colocasia is believed to have originated in the Indo-Malayan region and is the staple food in small isolated communities in the tropics. It is one of the ancient crops with an interesting history blending with the evolution of agricultural systems. It is one of the oldest crops in India. The common names of colocasia are taro, elephant ear, cocoyam, dasheen, eddoe, coco. In Hindi, its tubers are known as arvi, arbi and the leaves as patra, arvi patra.

It is an important root crop of India. It can be grown in tropical, sub-tropical and warmer temperate zones. Being tolerant to waterlogging it can be grown near water sources. It cannot withstand frost. This crop can be taken up by small and marginal farmers as its cultivation involves minimum risk. In India, it is mainly cultivated in Eastern and Southern states, viz. Andhra Pradesh, West Bengal, Uttar Pradesh, Bihar, Kerala, Odisha and Tamil Nadu. In natural habitat, it is commonly found near water sources in North-eastern India.

It is used as secondary staple food in Pacific islands and as a vegetable in Africa, India, and other South East Asian countries. The flesh of the tuber may be white, creamy or tinted with yellow, magenta or purple; these colours may remain in the cooked flesh. In consistency the flesh is more cheesy or slimy than that of a potato. Prior to eating, the tubers may be steamed, boiled or baked or they may be salted or dried and kept for use in the future.

The leaves, petioles, corms and cormels are edible. In many countries the leaf stalks of small leaves or the upper portions of larger leaves of different varieties, especially those with a purple pigmentation are cut for food. Often this is done at the time of harvesting the tubers and thus two different crops are obtained together.

The corm is rich in starch which contains 17–25% amylose. *Arvi* is recommended for gastric patients and its flour is good baby food. In India it is used as a vegetable or as subsidiary food after roasting, baking or boiling. The leaves and petioles are cooked like other green leafy vegetables.

Botany

Taro (*Colocasia esculenta*) belongs to the family Araceae and the genus *Colocasia.* The subfamily Colocasioideae of family Araceae consists of three edible tuber crops namely taro (*Colocasia esculenta*), tannia (*Xanthosoma* spp.) and giant taro (*Alocasia* spp.). Amongst these three crops, taro or arvi is important as vegetable throughout India.

Colocasias are herbaceous perennial tuber vegetable plants up to 2 m tall and have underground corms. The leaves are large with long petiole clasping at the base. The underground parts consists of one or more large edible central corms and a large number of cormels which are also known as tubers. Corms are cylindrical with short internodes. Root system is shallow and fibrous. Many cultivars do not flower.

Two botanical varieties of taro are recognised, namely, *Colocasia esculenta* var. *esculenta* (daseen form of taro) and *C.esculenta* var. *antiquorum* (eddoe form of taro). Dasheen types have large main corm and 4–8 sucker cormels. Eddoes types have small to medium sized main corm and a large number of edible cormels (15–20 or more).

Improved cultivars

CO 1: This variety is released by TNAU, Coimbatore. It yields 243 q/ha. Tubers have high starch content of 22.5% and higher protein content of 2.4%. Tubers have less acidity and good cooking quality.

Punjab Arvi-1: This variety of colocasia is released by PAU, Ludhiana. Its plants are tall, leaves dark green, large and obliquely erect. Petiole is long and sheathering at the base. The corms are brown, long of medium thickness with creamy inner flesh. The variety takes 176 days for maturity. Its average yield is 225 q/ha.

Sree Rashmi: Released by CTCRI, Thiruvanthapuram. All parts of the plant namely leaf, petiole, corm and cormels are non-acrid. Corms are big and cormels are medium size. The cormels have good cooking quality and taste with 15% starch and 25% protein. Crop duration varies from 7–8 months wilh an average yield of 150–200 q/ha.

Sree Pallavi: Released by CTCRI, Thiruvanthapuram. Corms are relatively big and cormels are small and more in number. Cormels have good cooking-quality and taste harvesting 16–17% starch content and 2–3% protein content. It takes around 6–7 months from planting to harvesting and yields 150- 180 q/ha.

Sree Kiran (F1): This is the first colocasia hybrid released by CTCRI, Thiruvanthapuram. This has recorded higher tuber yield

Muktakeshi: This is a colocasia variety released by the CTCRI Regional Centre. It is resistant to colocasia leaf blight disease with an average tuber yield of 250–300 q/ha. The tubers have excellent cooking quality.

Climate and soil

An observation of the natural habitat of taro along water sources, *viz.* banks of rivers and channels would reveal that the crop prefers flooded condition. It loves moist condition. But can be grown as a summer as well as rainy season crop. It is

cultivated on hills and plains of North-eastern India as a rainfed crop, where the rainfall is copious. A well distributed rainfall of about 1000 mm during cropping period is good for optimum tuber yield. In areas where rainfall is less, supplementary irrigation is required for successful production. It requires a mean daily temperature of 21–27°C. It survives well at high altitudes on hills in the North-eastern region if frost free condition remains at least for six months. Well drained fertile sandy soil is best suited for the cultivation of this crop. It also comes up well in fertile loamy to clay soils. The soil should have good moisture retention capacity. It can stand well in heavy soils and withstand waterlogged condition. The pH range of 5.5–7.0 is found to be ideal for the crop.

Cultural requirements

Planting time: Planting is usually done during rainy season but can also be done throughout the year under irrigated condition. In temperate regions, planting is avoided during winter.

Planting material: Arvi is vegetatively propagated. The cormels (side tubers) as well as the mother corm can be used as planting materials, but using cormels is better. Cormels weighing about 20–34 g form good planting material. They should be free from disease end injuries. The requirement of planting matertal is approximately 1,000 kg or 37,000 tuber/ha of land.

Land preparation and planting: According to soil type and management practices different methods of land preparation may be followed. Whatever be the preparatory cultivation method, the main objective is to give proper soil condition for tuber development and prevent percolation of impounded water. Ploughing the land 2–3 times to a depth of 20–25 cm and bringing it to a fine tilth is very essential. Farm yard manure or compost may be applied at the rate of 10–15 tonne/ha during land preparation. 30 kg N, 60 kg P and 30 kg K/ha should be applied before planting or within a week after sprouting.

In loamy soils pit method is better, whereas in alluvial soils raised mounds or beds are preferred. Under irrigated condition ridges and furrows system may be adopted. The planting is done in beds, pits or ridges and furrows. It is planted on ridges and furrows in parts of South India and in beds in North-eastern India.

The cormels can be planted at a spacing of 60 cm × 45 cm to a depth of 2.5–7.5 cm. In ridge and furrows system, ridges can be formed at 60 cm apart and cormels can be planted by giving 45 cm spacing. Plant the tuber with its top up; if in doubt, plant the tuber sideways and let nature figure it out. Cover the tuber with soil and water deeply. After watering, about 2.5- 5 cm of soil should cover the tuber. Mark the spot where the tuber is planted.

Flat bed method is adopted in upland with good drainage in which the cormels can be planted with same spacing (60 cm × 45 cm) in small pits.

Intercultural operations

Planted seed tubers take 30–45 days for germination. Under field conditions 5–10% of the seed tubers fail to germinate. To overcome this situation about 2,000–3,000 corms or cormels per hectare may be planted in the nursery at a close spacing so that seedlings from the nursery can be used for gap filling.

Soon after planting, cover the ridges with suitable mulching materials for retention of moisture and to control weeds. The planted tubers need to be mulched with green or dry leaves. It is important to hasten the germination, control weed growth, regulate soil temperature and also to retain soil moisture. Thus mulching with leafy material after planting is essential.

Irrigation throughout the growing season increases yield of corms and cormels. The number of irrigations required for maximum yield of cormels under summer condition have been recorded to be 5–10 for different areas. In case of failure of rain, it is very essential to give protective irrigation if the crop is grown under rain fed condition.

30 kg N and 30 kg K/ha is applied as top dressing one month after the first application along with weeding and earthing up. Desuckering is done at the time of second earthing up and only three suckers per plant are to be retained.

Pest and disease management

Diseases

Leaf blight: It caused by *Phytophthora colocasiae*, is a major disease commonly occurring in wet land conditions. This disease is a menace throughout the country except in some parts of South India. The disease appears on foliage as purple to brown water soaked spots of 1–2 cm diameter. It appears on tip of leaves or on margin. It is found that repeated planting of colocasia on same piece of land enhances disease incidence. Colocasia blight can be controlled by spraying zineb, mancozeb or copper oxychloride formulations at 2 g/l of water. Wherever colacasia is grown in rotation with other vegetables under irrigated condition there is less incidence of this disease.

Mosaic viral disease: In Southern states, mosaic viral disease is also being observed which can be overcome by using disease free planting material.

Pythium rot: It is a soil-borne disease which infects the corms by rotting is often noticed which can be avoided by crop rotation and use of healthy planting material.

Insect pests

The crop is found to be infested with leaf aphids, thrips, spider mites and leaf eating caterpillars mainly *Spodoptera* species.

Spraying of quinolphos or dimethoate or fenthion at 0.05% is helpful in controlling these pests. Repeat the spraying after 3–4 weeks if the infestation continues.

Dipping of seed cormels in 0.05% solution of monocrotophos or dimethoate for 10 minutes before planting is also recommended.

Harvesting and yield

Crop will be ready for harvest in 7–8 months after planting. One month prior to harvesting, all the suckers may be wrapped around the base of the mother plant and covered with soil by earthing up, for arresting further vegetative growth and sprouting of tubers. After doing this, irrigation has to be stopped to hasten maturity.

Maturity is indicated by yellowing and drying up of leaves. Harvesting is done by carefully uprooting the plants. By using hoes or spades, the entire plant is to be pulled out and then the corms are separated. Trim most of the green vegetation (top growth) off the top of the tubers: leave no more than 2–3 cm of leafy growth on the tuber. Let the freshly trimmed tubers sit in open air so that they can visibly dry out before final storage. Drying out will minimize the potential for mold, and bacteria to develop. The mother corms and cormels are separated and marketed.

The yield also varies with maturity. The corm yield ranges from 150–200 q/ha. The tubers can be stored during the colder, winter months in a cool, dry place. Do not store in a plastic bag: a plain paper bag with plenty of holes for ventilation will do nicely, as will storage in sphagnum peat moss or garden vermiculite. When the warm season comes around again, separate the tubers as necessary, plant anew (Chandy, 2013).

Planting material production

Inflorescences are very rarely produced by the taro plant and seeds are only known to have been developed in Hawaii, New Guinea and Dominica. Propagation for two thousand years has been vegetative. During this time many varieties have arisen in many countries and have been locally selected for this or that particular virtue.

The side tubers to be used as planting materials are usually separated from the mother corm and stored. Keep seed tubers in sand spread over the floor to avoid rotting. That is, larger corms are divided to collect offsets (cormels) and these cormels are used for planting. In the Pacific area the severed top of the main tuber is normally employed for propagation. In Trinidad both tops and lateral corms or *suckers* are used.

ELEPHANT FOOT YAM

Elephant foot yam or Amarphophallus is native of Tropical Asia.The distribution of this species is from India and Ceylon through Indo-China and Malaya to Java in the South and Philippines in the East. These are typical lowland plants, growing in the tropical and subtropical zones of the paleotropics, from West Africa to the Pacific Islands. Most species are endemic. They grow preferentially on disturbed grounds, such as secondary forests. Elephant foot yam is also known as white spot giant arum, stink lily. It is popularly known as *zamikand, suran, sooran* in Hindi.

It is a tropical tuber crop that offers excellent scope for adoption in the tropical countries as a cash crop due to its production potential and popularity as a vegetable in various delicious cuisines. It is traditionally cultivated on commercial scales in the states of Andhra Pradesh, Tamil Nadu, Kerala, West Bengal and Goa. The yam is used as a vegetable as well as for preparation of chips, pickles and others. The plant is also famous for its medicinal values. The corm of Elephant foot is eaten as a vegetable, usually boiled or baked. Elephant yam is also sometimes grown for its medicinal properties.

The tubers are rich in nutrients. Pickles and many indigenous medicinal preparations are also made using its tubers. In India, it has attained the status of a

cash crop and the area under its cultivation is increasing fast.

Botany

Elephant foot yam [*Amorphophallus paeoniifolius* (Densst) Nicolson; syn: *Amorphophallus companulatus* Blume] belongs to the family Arace*ae* and the genus *Amorphophallus. Amorphophallus* is a large genus of some 170 tropical and subtropical tuberous herbaceous plants. A few species are edible as "famine foods" after careful preparation to remove irritating chemicals. These small to massive plants grow from a subterranean tuber, *Amorphophallus* tubers vary greatly from species to species, from the quite uniformally globose tuber of *A. konjac* to the elongated tubers of *A.longituberosus* and *A.macrorhizus* to the bizarre clustered rootstock of *A.coaetaneus*. From the top of this tuber a single leaf, which can be several metres across in larger species, is produced atop a trunk like petiole followed, on maturity, by a single inflorescence. This leaf consists of a vertical leaf stalk and a horizontal blade, which may consist of a number of small leaflets.

The leaf lasts one growing season. The petiole (the primary flower stalk) can be long or short. A striking character of the genus, of about 80 species, is the development, from an underground tuber, of a terminal inflorescence, often evil smelling, and which may be enormous, when the plant is leafless; after fruiting the single leaf develops. The tuber is a rather flattened rough and knobby sphere which may weigh as much as 5–15 kg. The single leaf grows to a height of 60–180 cm, the blade of which is divided into numerous leaflets, and may be from 90–240 cm across. Tubers are not eaten except by very primitive jungle people after thorough preparation.

As is typical of the Arum family, these species develop an inflorescence consisting of an elongate or ovate spathe (a sheathing bract) which usually envelops the spadix (a flower spike with a fleshy axis). The spathe can have different colors, but mostly brownish purple or whitish green. On the inside, they contain ridges or warts, functioning as insect traps. The plants are monoecious. The spadix has tiny flowers: female flowers, no more than a pistil, at the bottom, then male flowers, actually a group of stamens, and then a blank sterile area. This last part, called 'the appendix', consists of sterile flowers, called staminodes, and can be especially large. There is no corolla. Once the spathe opens, pollination must happen the same day. The inflorescence, in many species, emits a scent of decaying flesh, in order to attract insects, though a number of species give off a pleasant odor. Through a number of ingenious insect traps, pollinating insects are kept inside the spathe to deposit pollen on the female flowers, these stay receptive for only one day, while the male flowers are still closed. These open the next day, but by then female flowers are no longer receptive and so self pollination is avoided. The male flowers shower the trapped insects with pollen. Once the insects escape, they can then pollinate another flower.

Improved cultivars

Sree Padma: This is developed by CTCRI, Thiruvanthapuram. This is high yield variety combined with good cooking quality. It gives an yield of 410 q/ha.

Sree Athira: This is developed by CTCRI, Thiruvanthapuram. This is the first

genetically improved elephant foot yam variety.

Gajendra: This variety was developed by CTCRI, Thiruvanthapuram. It is a local high yielding selection from Kovvur area of Andhra Pradesh. It produces smooth corms, free from daughter corms. The cooking quality is very good and totally free from acridity. The tubers are well shaped and generally devoid of cormels or propagules. It gives an yield 500–600 q/ha. This performs very well in eastern and northern India.

Sree Padma: This variety was developed by CTCRI, Thiruvanthapuram. The tubers are non acrid and generally have one mother corm and a few cormels or propagules. It has a yield potential of 400 q/ha.

Bidhan Kusum: This variety was developed by Vidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, West Bengal.The tubers are nonacrid, well shaped and generally devoid of cormels or propagules. It gives an average yield of 500–600 q/ha.

Santragachi: This is a medium yielding popular local cultivar of West Bengal having several rough daughter corms. The flesh is light cream with slight acridity. This is popular in eastern India.

Climate and soil

Elephant foot yam, grows well in hot (25–35° C) and humid (80–90% RH) climate. Hot and humid climate is required at initial stages of the crop growth for vigorous growth, whereas dry climates facilitate tuber bulking at later stage. Well distributed rainfall of 1000–1500 mm is helpful for good growth and tuber yield. The crop can be grown in any soil types by raising the crop in pits filled with well decomposed cow dung and sandy loam soil; although well drained, fertile, sandy loam soil is ideal for elephant foot yam cultivation.

Cultural requirements

Planting time: Elephant foot yam is a long duration crop and generally attains maturity in 6–7 months. Under irrigated conditions, it is planted in summer (March) and attains maturity by November. Under rainfed conditions, the crop is planted at the onset of monsoon, preferably in June. Depending on the market's demand, the harvesting can be started after 5–7 months. This crop has the sustainability to grow at any time of the year, provided, temperature is congenial and adequate soil moisture is available.

Planting material: The tubers undergo a dormancy period of 45–60 days. It is usually propagated by offsets or corms. The offsets are miniature tubers which grow out of the parent corm and are called daughter corms. Traditionally farmers take advantage of the dormancy period by planting during February and March so that the sets would sprout with the premonsoon showers.

Initial size of planting material plays a significant role in determining the final size of the harvested tubers. Results of research have shown that 400–500 g size whole tubers were more suitable for raising a commercial crop. Tubers of 3–4 kg can be harvested after six to seven months. This size is most suitable from marketing and transport point of view.

Tuber cut pieces weighing about 1 kg are ideal for planting. Dip the pieces in

cow dung slurry and allow to dry under shade before planting. After planting, cover the pit with dried leaves or other mulching materials. About 12,000 cut pieces weighing about 12 t are required for planting one hectare. Most of the seed material will germinate within one month after planting. Mealy bugs usually attack the corm in field and store. Avoid planting corms already infested.

Although cut tubers can also be used as planting material, the use of whole tuber is significantly superior over cut tubers in terms of sprouting percentage and overall yield.

Land preparation and planting: The main field should be thoroughly ploughed, levelled and tilled before planting. Elephant foot yam has high nutrient requirement. Well decomposed farmyard manure @ 25 tonne/ha mixed with soil should be filled in pits.

The planting should be done at a spacing of 90 cm × 90 cm for commercial crop. The pits of 60 cm × 60 cm × 60 cm size should be dug out and refilled with the top soil mixed with 5–10 kg FYM before planting, for facilitating tuber bulking.

Tubers are planted shallow (20 cm), as deep planting would interfere with the harvest operations, besides most of its feeder roots are found on the surface. Before planting it is advisable to treat the tubers with cow dung slurry mixed with *trichoderma* formulation followed by drying under shade. When cut tubers are used for planting, certain precautions and treatments are needed as cut tubers are prone to decay after planting due to possible presence of several soil borne pathogens. Cut tuber pieces of 50–100 g are treated in thick cow dung slurry mixed with mancozeb (0.2%) + monocrotophos (0.05%) for 5–10 minutes, followed by drying in shade for 24 hours.

Intercultural operations

Immediately after planting, the pits are mulched with dried leaves which will induce better sprouting by conserving moisture. Mulching with organic waste or polyethylene sheets helps in reducing the weed growth and conserving soil moisture. For summer crop, a light irrigation should be provided immediately after planting. Depending on the soil moisture availability, irrigation should be given at regular intervals till the arrival of monsoon. Care should be taken to prevent water stagnation at every stage of crop growth. Irrigation should be withdrawn during the later stage of crop growth after 5–6 months of planting to allow the crop to mature. 2–3 weedings are done in the first few months.

A fertilizer dose of 100 kg N, 80 kg P and 100 kg K/ha has been found to be optimum. The fertilizer dose should be decided depending on the soil type and nutrient status. Full dose of P (80 kg) and half the dose of N (50 kg) and K (50 kg) should be applied after forty five days of planting along with intercultivation and weeding. The second dose of N (50 kg) and K (50 kg) should be applied one month after the first application along with intercultivation and earthing up. Irrigation is to be done as and when required.

During the initial period of 2–3 months after planting, crops like leafy vegetables, green gram, black gram, cowpea, cucumber; etc can be grown as intercrop. Intercropping of elephant foot yam in banana, coconut and other newly planted orchards gives additional income to farmers.

Harvesting and yield

Elephant foot yam becomes ready for harvest in about 8–9 months after planting. The crop attains maturity when total senescence takes place and yellowing and drooping of the leaves indicates crop maturity. The corms can be harvested 7–10 months after planting. After full maturity the corms are dug out, cleaned and stored in well ventilated room. The corm yield ranges from 750–1000 q/ha.

Pest and disease management

The crop is free from major pests and diseases except color rot caused by *Sclerotium rolfii*. Waterlogging, poor drainage and mechanical injury at the color region favour disease incidence. Disease can be managed by use of disease free planting material, removal of infected plants, improving drainage, application of neem cake to the soil, and drenching the soil with captan (0.2%).

Planting material production

Fully mature, graded and cured tubers should only be used for storage as planting material. The storage place should be well ventilated and cool. The tubers should be stored in a single layer. But if the storage place is insufficient, then they can be stored in two layers. Storing the tubers in a heap should be avoided.

YAMS

Yams are a primary agricultural commodity in West Africa and New Guinea. They were first cultivated in Africa and Asia about 8,000 BC. Due to their abundance and consequently, their importance to survival, the yam was highly regarded in Nigerian ceremonial culture and used as a vegetable offered during blessings. Yams are still important for survival in these regions. The tubers can be stored up to six months without refrigeration, which makes them a valuable resource for the yearly period of food scarcity at the beginning of the wet season. Historical records in West Africa and of African yams in Europe date back to the 16th century. Yams were taken to the Americas through precolonial Portuguese and Spanish on the borders of Brazil and Guyana, followed by a dispersion through the Caribbean. In many societies yams are so important that one can speak of a 'yam civilization'. Growing the tuber is associated with magic; the best ones must be given to the chief or king; there is a series of myths connected to a divine origin; a farmer may gain a lot of prestige by growing the largest or longest yam. White Guinea yam and water yam are the most important food yams in terms of cultivation and utilization. Yam tubers may be eaten with sauce after boiling, roasting, or frying in oil. The tubers may also be mashed or pounded into dough after boiling, processed into flour, or cooked into pottage with added protein sauce and oils. In addition to their food and market values, yams play a major role in sociocultural life for a wide range of small holder households especially in the dominant production zone of West Africa. Consumer demand for yam is generally very high in this subregion and yam cultivation is very profitable despite high production costs.

Yam provides around 110 calories per 100 g of product. Yam is high in vitamin C and B_6, potassium, manganese and dietary fibre while being low in saturated

fat and sodium. A product that is high in potassium and low in sodium is likely to produce a good potassium sodium balance in the human body, and so protects against osteoporosis and heart disease.

Botany

Yam is the common name for some species in the genus *Dioscorea* and the family Dioscoreaceae. Yams (*Dioscorea* species) are annual or perennial tuber bearing and climbing plants. The genus *Dioscorea* has over 600 species but only a few are cultivated for food or medicine. The major edible species of African origin are white Guinea yam (*D. rotundata* Poir.), yellow Guinea yam (*D. cayenensis* Lam.), and trifoliate or bitter yam (*D. dumetorum* Kunth).

Yams are perennial herbaceous vines cultivated for the consumption of their starchy tubers in Africa, Asia, Latin America, and Oceania. There are many cultivars of yam. The tubers are underground stems which bulk as the starch accumulates and are usually single with variation in size and shape.

Yam tubers can grow up to 1.5 m in length and weigh up to 70 kg and 7.5–15 cm high. The vegetable has a rough skin which is difficult to peel, but which softens after heating. The skin vary in colour from dark brown to light pink. The majority of the vegetable is composed of a much softer substance known as the "meat". This substance ranges in colour from white or yellow to purple or pink in ripe yams.

Edible species from Asia include water yam or greater yam (*D. alata* L.), lesser yam (*D. esculenta* [Lour.] Burkill), and cush cush yam (*D. trifida* L.) originated from the Americas. Major cultivated species are as under:

Dioscorea alata, called as greater yam, water yam, winged yam and purple yam, was first cultivated in Southeast Asia. Although not grown in the same quantities as the African yams, it has the largest distribution worldwide of any cultivated yam, being grown in Asia, the Pacific islands, Africa, and the West Indies. In the United States it has become an invasive species in some southern states.

Dioscorea esculenta, the lesser yam, was one of the first yam species cultivated. It is native to Southeast Asia and is the third most commonly cultivated species there, although it is cultivated very little in other parts of the world. Its vines seldom reach more than 3 m in length and the tubers are fairly small in most varieties. The tubers are eaten baked, boiled, or fried much like potatoes. Because of the small size of the tubers, mechanical cultivation is possible; which, along with its easy preparation and good flavor, could help the lesser yam to become more popular in the future.

Dioscorea rotundata, the white yam, and ***Dioscorea cayenensis***, the yellow yam, are native to Africa. They are the most important cultivated yams. In the past they were considered two separate species but most taxonomists now regard them as the same species. They are large plants; the vines can be as long as 10–12 m. The tubers most often weigh about 2.5–5 kg each but can weigh as much as 25 kg. After 7 to 12 months growth the tubers are harvested.

Dioscorea bulbifera, the air potato, is found in both Africa and Asia, with slight differences between those found in each place. It is a large vine, 6 m or

more in length. It produces tubers; however the bulbils which grow at the base of its leaves are the more important food product. They are about the size of potatoes (hence the name "air potato"), weighing from 0.5–2 kg. Some varieties can be eaten raw while some require soaking or boiling for detoxification before eating. It is not grown much commercially since the flavor of other yams is preferred by most people. However it is popular in home vegetable gardens because it produces a crop after only four months of growth and continues producing for the life of the vine, as long as two years. Also the bulbils are easy to harvest and cook.

Dioscorea trifida, the cush cush yam, is native to the Guyana region of South America and is the most important cultivated New World yam. Since they originated in tropical rain forest conditions their growth cycle is less related to seasonal changes than other yams. Because of their relative ease of cultivation and their good flavor they are considered to have a great potential for increased production.

Dioscorea opposita, Chinese yam, is native to China. The Chinese yam plant is somewhat smaller than the African, with the vines about 3 m long. It is tolerant to frost and can be grown in much cooler conditions than other yams. It is now grown in China, Korea, and Japan. It was introduced to Europe in the 19th century when the potato crop there was falling victim to disease, and is still grown in France for the Asian food market. The tubers are harvested after about 6 months of growth. Some are eaten right after harvesting and some are used as ingredients for other dishes, including noodles, and for traditional medicines.

Greater yam

Climate and soil

Greater yam (*Dioscorea alata*) is predominantly a tropical plant. The crop cannot withstand frost and excessively high temperatures. Temperature around 30°C and rainfall of 120–200 cm distributed throughout the growth period are ideal. Day length greater than 12 hours during initial stages and shorter day length during the later part of the growing season favour satisfactory tuber formation. It requires loose, deep, well-drained, fertile soil. The crop does not come up well in waterlogged conditions.

Improved cultivars

Sree Keerthi: This variety is developed by CTCRI, Thiruvanthapuram. Suitable for intercropping in mature coconut garden and with banana.

Sree Roopa: This variety is developed by CTCRI, Thiruvanthapuram. Possesses excellent cooking quality.

Indu: This variety is developed by CTCRI, Thiruvanthapuram. This is recommended as a pure crop and also as an intercrop of coconut in the reclaimed alluvial soils of Kuttanad.

Sree Shilpa: This variety is developed by CTCRI, Thiruvanthapuram. This is the first hybrid having good culinary quality. The crop matures early, within 8 months. The tubers have 33–35% dry matter, 17–19% starch, 1.4–2% protein and 0.8–1.2% sugar. Developed by CTCRI, Thiruvanthapuram.

Sree Karthika: This variety is developed by CTCRI, Thiruvanthapuram. High yiled, excellent cooking quality. The crop matures within 9 months. The tubers have 21.42% starch, 1.14% sugar and 2.47% crude protein.

CO 1: This variety is released by TNAU, Coimbatore. It yields 448 q/ha of tubers/ha in a crop a duration of 8 to 8.5 months. The tubers are big with white flesh. Tubers are rich in carbohydrate (28%) and protein (2.5%).

Cultural requirements

Planting time: Seed tubers are normally planted during the later part of the dry season (March-April) and start sprouting with the onset of premonsoon showers. If the planting is delayed, yams start sprouting in storage, which is not desirable for planting.

Planting material: *D. alata* produces mostly a single big tuber in which only one head end of the tuber is available as good seed material. For getting the head end in each propagation unit, the whole tuber is divided longitudinally. Each piece of cut tuber should weigh at least 250–300 g. Dip the pieces in cowdung slurry and allow to dry under the shade before planting. About 2500–3000 kg of seed material is required to cover one hectare of land.

Land preparation and planting: The main field is ploughed 3–4 times. Pits of 45 cm × 45 cm × 45 cm size are prepared at a spacing of 90 cm × 90 cm for greater yam. Fill up three fourth of each pit with 1–1.25 kg of cattle manure or compost and mix with topsoil. Apply cattle manure or compost at 10–15 tonne/ha as basal dressing. Then the mounds are formed. Plant the cut tuber pieces and completely cover the pit with leafy materials to conserve soil moisture and maintain optimum temperature. The tuber piece or the entire corm can be used for planting. The tubers are planted at the centre of the mounds at a depth of 30–40 cm. A fertilizer dose of 80 kg N, 60 kg P and 80 kg K/ha has to be applied in two split doses.

Intercultural operations

Irrigation should be given immediately after planting. Then onwards irrigation is done regularly as and when required. Mulching immediately after planting is beneficial for increasing the tuber yield. 2–3 weedings should be done. 40 kg N, 60 kg P, 40 kg K/ha is applied within a week after sprouting; 40 kg N and 40 kg K/ha is applied one month after the first application along with weeding and earthing up. The vines are to be staked on strong bamboo poles of 2 m height. The vines are to be staked on strong bamboo poles of 2 m height. Or Trail the vines by fixing small poles attached with coir rope and direct 4–6 plants per pole. Trailing is essential to expose the leaves to sunlight. Trailing has to be done within 15 days after sprouting by coir rope attached to artificial supports in the open areas or to trees where they are raised as an intercrop. When grown in open areas, trail to a height of 2–3 m. Trail the vines properly as and when side shoots are produced.

Pest and disease management

Yam scale is found to infest the corms both under field and storage situations. Yam tubers infested by yam scale insects which appear as whitish specks on the

skin of yam tubers. These insects can be controlled by dipping the seed tubers in monocrotophos (0.05%) solution before planting.

Harvesting and yield

The greater yam comes to harvest 8–10 months after planting. The maturity of the tubers is indicated by the yellowing and drying of leaves. The tubers are dug out without causing injury. The tuber yield in greater yam ranges from 200–400 q/ha,

Lesser Yam

Climate and soil

Lesser yam (*Dioscorea esculenta*) is predominantly a tropical plant. The crop cannot withstand frost and excessively high temperatures. Temperature around 30ºC and rainfall of 120–200 cm distributed throughout the growth period are ideal. Day length greater than 12 hours during initial stages and shorter day length during the later part of the growing season favour satisfactory tuber formation. It requires loose, deep, well-drained, fertile soil. The crop does not come up well in waterlogged conditions.

Improved cultivars

Sree Latha: This variety is released by CTRI, Thiruvanthapuram. The crop duration is 8 months. Tubers are oblong to fusiform with creamy white flesh. Vines twine to the left.

Sree Kala: This variety is released by CTRI, Thiruvanthapuram. This is an early variety with 7.5 months duration. The tubers have 35–37% dry matter, 23–25% starch and 1–1.3% sugar.

Cultural requirements

Planting time: Seed tubers are normally planted during the later part of the dry season (March-April) and start sprouting with the onset of pre-monsoon showers. If the planting is delayed, yams start sprouting in storage, which is not desirable for planting.

Planting material: The 1,800–2,700 kg of planting materials are required for 1 ha land.

Land preparation and planting: The main field is ploughed 3–4 times. Pits of 20 cm × 20 cm × 20 cm size are prepared at a spacing of 75 cm × 75 cm for lesser yam. These pits are filled with the mixture of 1 kg farmyard manure and top soil. Apply cattle manure or compost at 10–15 tonne/ha as basal dressing. Then the mounds are formed.

Select medium size tubers weighing about 100–150 g each. Plant the whole tuber, one in each mound and cover completely with soil. Mulch the mounds to maintain optimum temperature and moisture. The tuber piece or the entire corm can be used for planting. The tubers are planted at the centre of the mounds at a depth of 30–40 cm.

Intercultural operations

Irrigation should be given immediately after planting. Then onwards irrigation is done regularly as and when required. Mulching immediately after planting is beneficial for increasing the tuber yield. 2–3 weedings should be done.

A fertilizer dose of 80 kg N, 60 kg P and 80 kg K/ha has to be applied in two splits; half dose of N (40 kg), full dose of P (60 kg) and half of K (40 kg) within a week after sprouting; remaining half N (40 kg) and half K (40 kg) one month after the first application along with weeding and earthing up.

The vines are to be staked on strong bamboo poles of 2 m height. The vines are to be staked on strong bamboo poles of 2 m height or trail the vines by fixing small poles attached with coir rope and direct 4–6 plants per pole.

Pest and disease management

Yam scale is found to infest the corms both under field and storage situations. Yam tubers infested by yam scale insects which appear as whitish specks on the skin of yam tubers. These insects can be controlled by dipping the seed tubers in monocrotophos (0.05%) solution before planting.

Harvesting and yield

The crop is ready for harvest by about 7–8 months time. The maturity of the tubers is indicated by the yellowing and drying of leaves. The tubers are dug out without causing injury. Tuber yields of 200–250 q/ha can be obtained by following the improved methods of cultivation.

White yam

White yam or African yam (*Dioscorea rotundata*) is a new crop species of edible yam introduced from Nigeria.

Climate and soil

White yam is predominantly a tropical plant. The crop cannot withstand frost and excessively high temperatures. Temperature around 30ºC and rainfall of 120–200 cm distributed throughout the growth period are ideal. Day length greater than 12 hours during initial stages and shorter day length during the later part of the growing season favours satisfactory tuber formation. It requires loose, deep, well drained, fertile soil. The crop does not come up well in waterlogged conditions.

Improved cultivars

Sree Subhra: This variety is developed by CTCRI, Thiruvanthapuram. The tuber contains 27–28% dry matter, 21–22% starch and 1.8–2% protein. It is drought tolerant with 9–10 months duration.

Sree Priya: This variety is developed by CTCRI, Thiruvanthapuram. The tuber contains 25–27% dry matter, 19–21% starch and 2–2.5% protein. It is drought tolerant and duration is 9–10 months. It is suitable for inter-cropping in mature coconut garden and with banana.

Sree Dhanya: This variety is developed by CTCRI, Thiruvanthapuram. It is

the first dwarf variety. The tubers have 28–30% dry matter, 22–24% protein and 0.3–0.5% sugar.

Cultural requirements

Planting time: Seed tubers are normally planted during the later part of the dry season (March-April) and start sprouting with the onset of premonsoon showers. If the planting is delayed, yams start sprouting in storage, which is not desirable for planting.

Planting material: To plant one hectare 1,800–2,700 kg of seed materials are required.

Land preparation and planting: The main field is ploughed 3–4 times. Pits of 20 cm × 20 cm × 20 cm size are prepared at a spacing of 75 cm × 75 cm for lesser yam. farmyard manure (FYM) @15 tonne/ha is applied at the time of land preparation. These pits are filled with the mixture of 1 kg FYM and top soil. Then the mounds are formed.

Select medium size tubers weighing about 100–150 g each. Plant the whole tuber, one in each mound and cover completely with soil. Mulch the mounds to maintain optimum temperature and moisture. The tuber piece or the entire corm can be used for planting. The tubers are planted at the centre of the mounds at a depth of 30–40 cm.

Intercultural operations

Irrigation should be given immediately after planting. Then onwards irrigation is done regularly as and when required. Mulching immediately after planting is beneficial for increasing the tuber yield. 2–3 weedings should be done.

The NPK fertilizers @ 100:50:100 kg/ha is applied. Full dose of P fertilizer along with 50% of N and K fertilizers are to be applied when 50% of the planted setts sprout. The balance 50% of N and K fertilizers are applied as top dressing, 1 month after the first application which could be combined with intercultural operations. The vines are to be staked on strong bamboo poles of 2 m height or Trail the vines by fixing small poles attached with coir rope and direct 4–6 plants per pole.

Pest and disease management

Yam scale is found to infest the corms both under field and storage situations. Yam tubers infested by yam scale insects which appear as whitish specks on the skin of yam tubers. These insects can be controlled by dipping the seed tubers in monocrotophos (0.05%) solution before planting.

Harvesting and yield

White yam comes to harvest 7–8 months after planting. The maturity of the tubers is indicated by the yellowing and drying of leaves. The tubers are dug out without causing injury. The tuber yield in white yam ranges from 350–400 q/ha.

Planting material production

Rapid seed yam production or mini sett technique is used for production of

planting material in white yam. In this method clean and healthy yam tubers weighing about 1 kg are cut into cylindrical (disc like) pieces, each about 5 cm thick. From each such piece, 2–4 small pieces (30 g) could be obtained by cutting the disc longitudinally or along the two perpendicular diameters. Such a piece is called a "mini sett". The mini setts are then spread out under light shade for an hour with cut surface facing upwards before planting them in the nursery seedbeds. The mini setts take 2–3 weeks for sprouting. At this stage, they are transplanted to the main field at a spacing of 50 cm on ridges prepared 1 m apart.

YAM BEAN

Yam bean is indigenous within the Americas. It is grown in Latin America, typically in Mexico and Central America, and is a popular dietary staple in these regions. The other major species of yam beans are also indigenous within the Americas. It has a variety of common names including climbing yam bean, Mexican yam, Mexican potato, Mexican water chestnut, Mexican yam bean, Mexican turnip, Chinese turnip, Chinese potato, and jicama. In Hindi it is known as *sankalu*.

Jicama is a round, fleshy taproot vegetable of bean family plant. Its underground starchy root is one of the popular edible root vegetables grown in many parts of Central American, South Asian, Caribbean, and some Andean South American regions. Its refreshing, crispy, ice white fruit like pulp is eaten raw or cooked in a variety of sweet and savory dishes worldwide.

The sweet, juicy, crisp tubers are eaten raw or lightly cooked. To prepare, peel off the brown skin. The raw tubers taste like a cross between a water chestnut and an apple and do not discolour when cut. It is a great addition to salads and can be used as a crudité. It is also substituted for water chestnuts in stir-fry. In Mexico it is sliced thinly and sprinkled with salt, lemon juice and chilli sauce.

The seed pods and seeds are toxic and dangerous to eat. The pods contain rotenone, a toxic substance often used as an organic insecticide. Its seeds are rarely consumed. Yam bean seed poisoning is life threatening. Yam bean plant is a natural source of an organic poison (rotenone) – All parts of the plant above the soil; stems, leaves, flowers, seeds and seed pods contain levels of the insecticide, pesticide and piscicide (fish poison) rotenone. It is reported that people with young children should be aware of this fact. Also, upper parts of the plant should not be fed to animals.

The tuber is extremely nutritious because it contains a high amount of vitamin C, lesser amount sodium, and has no calories or fat. It is used to thicken soups and sauces in other countries. Yam bean tuber is high in carbohydrates in the form of dietary fibre. It is composed of 86–90% water; it contains only trace amounts of protein and lipids. Its sweet flavour comes from the oligofructose insul-in (also called fructooligosaccharide) which is a prebiotic (pre-biotics are non-digestible food ingredients that stimulate the growth and/or activity of bacteria in the digestive system in ways claimed to be beneficial to health).

Botany

Yam bean [*Pachyrhizus erosus* (L.) Urban] belongs to the family Fabaceae and the genus *Pachyrrhizus.* It is a vigorous, sub-tropical and tropical, climbing

legume vine from South America. It has similar growth characteristics as that of lima bean or any other bean species plant. The most distinguishing feature, however, is that it bears globular, fleshy, turnip like starchy edible root below the ground surface. Unlike other starch roots like potato and sweet potato wherein the peel may be eaten; jicama features thick dust brown color inedible skin. Inside, its white starchy flesh has crisp texture and fruit like succulent, sweet starchy taste. Each tuber weighs about 250 to 1200 g.

It has very pretty, big, blue pea flowers. Sadly the flowers should usually be removed as the bean pods and seeds are toxic, they also take a lot of vigour from the plant and reduce the harvest of tubers considerably. Let one plant go to seed for your next year's crop. Even though this plant is an herbaceous perennial, it is usually grown as an annual, because the root tuber, the perennial part, is also the bit harvested. Yam bean can be propagated from a tuber or seed. The plants die back in winter in cool climates but the tubers will shoot again in spring. The root of yam bean develops swellings the size of a large turnip (up to 5 per plant) under the surface of the ground. Even though this vine can reach 2–6 m tall, it is usually pruned to 1 to 1.5 m, as removing the flowers can double the yield of roots.

Yam bean or jicama plant contains significant levels of fat soluble organic toxin, rotenone. It is concentrated especially in the leaf tops, stems and seed pods and at much lower levels in the roots. Several studies found that it is linked to the development of Parkinson's disease. However, peeled roots are safe for human consumption, including in children. Rotenone works at cellular level inhibiting several metabolic enzymes like NADH dehydrogenase in the mitochondria. Outside, it is used as environmentally safe broad spectrum insecticide, piscicide (to poison fish), and pesticide.

There exist at least five cultivar types of *Pachyrhizus* species; however, the three popular cultivated varieties include *Pachyrhizus erosus* (Mexican yam bean), *Pachyuhizus ahipa* (Andean yam bean), *Pachyrhizus tuberosus* (Amazonian yam bean, jíquima) and *P. palmatilobus*, locally known as '*jícama de leche*'. *Pachyrlizus erosus* ('*jícama de leche*') or Mexican yam bean is the popular variety imported in the USA.

Breeding

Yam bean research in India has not received much attention from the national research system. Hence farmers in the country still rely on traditional land races. In India, research on yam bean is being undertaken at Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala and two Centers (Bihar and West Bengal) of the All India Co-ordinated Research Project on Tuber Crops (AICRPTC). There has been little attempt for genetic improvement through breeding. Breeding in yam bean is limited to selection only. Nature of compatibility was studied in a set of diallel crosses involving eight genotypes. The breeding objectives include earliness, high dry matter, improved nutrition, drought tolerance and pest and disease resistance. Attempts have already been made to develop hybrids of Mexican and local types and some of the lines were promising.

Improved cultivars

Rajendra Mishrikand 1 (RM-1): This variety is released by RC RAU, Dholi. This is very popular in Bihar and West Bengal. Its average tuber yield is 400 – 550 q/ha in 110 – 140 days. The individual tuber weighs 600–700 g, sweet, comparatively free from cracking with smooth surface, napiform with cream coloured tuber skin. Flesh is white.

L-19: This is a promising Mexican line which produces better yield in Bihar, West Bengal and Odisha.

Climate and soil

Yam bean requires a hot humid climate and adapts well in sub-tropical and hot temperate zones. The basic requirement is frost free condition during the growth period. It grows up to an altitude of 1000 m. It has been observed that thermoperiodism has got a definite effect on tuberization. Though yam bean requires 14–15 hours of photoperiod for good vegetative growth, shorter days are preferred for better tuberization. Hot days and cooler nights favour tuberization. A well distributed rainfall during the growth period is required for optimum tuber yield. Excessive rain is deleterious to the crop. Cool climate during early growth period adversely affects the tuber initiation and also results in a prolonged vegetative phase. Fertile, well drained, sandy loam soil is best suited for cultivation of yam bean. This crop adapts well to loamy and clay loam soil. It can tolerate a higher clay content if the soil is well drained with good humus content. Waterlogging adversely affects yam bean cultivation. Optimum soil pH requirement is 6.0–7.0.

Cultural requirements

Planting time: Traditionally yam bean is sown during June-July with the onset of rain in North-Eastern India and is usually harvested in December-January. The time of sowing of seeds varies from June to September according to the purpose for which the crop is grown.

Land preparation and sowing: Deep ploughing of land twice using a mould board plough is essential. Plank the soil after each ploughing to have a well pulverised soil as well as to conserve moisture. A good tilth is required for yam bean cultivation. Ridges and furrows are prepared at 30 cm distance. 25 tonne/ha of farmyard manure is applied at the time of land preparation. 40 kg N, 40 kg P, 80 kg K/ha is applied in the furrows and covered with soil. Irrigate the furrows 2 days before sowing.

For seed purpose, seeds are sown during June-July at a spacing of 30 cm × 30 cm. If smaller size tubers are required, seeds may be sown in August-September at a closer spacing of 30 cm × 15 cm or even 15 cm × 15 cm. Yam bean seeds can be sown on hills at the rate of 3–5 seeds per hill. Planting the seeds on ridges results in better yield. Soak the seeds in warm water overnight to soften the seed coat and to speed up germination. The depth of sowing should be 5 cm.

Yam bean is usually raised by seed. The seed rate varies according to the spacing adopted. Normal seed rate is 20–30 kg/ha depending upon the time of sowing, spacing and the purpose.

Intercultural operations

Normally, yam bean is grown as a rainfed crop but one or two irrigations particularly in the drier months promote tuber development. Frequent irrigation with higher doses of fertilizer makes tubers more succulent and reduces keeping quality. Normally there is no need to irrigate a June-July crop. In case there is scarcity of rains, irrigation is necessary as yam bean requires adequate moisture.

Weed infestation is more in a June - August sown crop compared to September sown crop. The field is kept weed free by mulching the crop. Mulching also regulates soil temperature and conserves soil moisture. The first interculturing is done at 40 days after sowing and the remaining half dose of nitrogen is applied along with earthing up. Second weeding is done 30 days after the first weeding.

The crop is top dressed with 40 kg N/ha 40–50 days after sowing along with interculturing and earthing up.

Pest and disease management

No serious pests are reported in yam bean. Root rot and mosaic are the common diseases. The *Sclerotium rolfsii* affects the crop under water-logged conditions. Providing good drainage prevents the disease incidence. Use of disease free seeds and field sanitation reduces the mosaic incidence. But when the crop is grown for seed purpose, pod borer becomes serious.

Harvesting and yield

In India, yam bean is harvested 150 days after sowing. But it can be harvested after 100 days according to the demand in the market and smaller sized tubers fetch better market price. However, optimum time of harvesting is 90 to 105 days. If harvesting is delayed, chances of cracking of tubers are more. This in turn results in the deterioration of tuber quality and thereby affecting market value. Shallow irrigation may be given just before digging the tubers manually. The above ground portions are trimmed before digging out the tubers. Harvested tubers can be stored for 2–3 days without any deterioration. If the tubers are stored for a longer period, the creamy colour of the skin changes to purplish brown and loses water, which causes reduction in weight.

The harvest can also be delayed by leaving the crop in the soil without removing top portion. The seed crop is usually harvested 240 days after sowing, i.e. during March-April. The tuber yield varies from 360 to 400 q/ha.

Seed production

As in other legumes. The seed pods are generally harvested when they start drying and beans obtained by beating the pods with sticks.

ARROWLEAF/ELEPHANT EAR

The arrowleaf/elephant ear or *Tannia* is the only aroid genus native to the American continent and was cultivated in the tropical Central and South America from ancient times and is widely used for food. *Tannia* is also known as cocoyam, tannier, *yautia*, *malanga* or new cocoyam is one of the six most important root and tuber crops grown worldwide and is attaining worldwide importance as energy

food. It may have originated in the northern part of South America and spread through the Antilles and Mesoamerica. When the Europeans arrived, it was further known to have been grown from southern Mexico to Bolivia in the Latin America. Only during the 19^{th} century, it spread widely throughout the tropical world. Now, it is cultivated in tropical America, the Caribbean, West Africa and the Pacific, and to a very limited extent in some other parts of the humid tropics.

Tannia is mainly cultivated by small-scale farmers in Asia, Africa and Latin America. In India, tannia is grown in maharashtra, Kerala, parts of Tamil Nadu, Karnataka, West Bengal and north-eastern states of India. The corm, cormels and leaves of tannia are an important source of carbohydrates vitamins and minerals for human nutrition and animal feed. The usable parts are the subterranean tuberous stems. The yellow or pinkish flesh is dense and starchy. It contains between 15 and 39% of carbohydrates, 2–3% of protein and 70–77% of water; it has more nutritional value than potato and is probably easier to digest. Besides the root, the young leaves are also edible and consumption of the young leaves is similar to spinach.

The starchy cormels occupy an important place in the diet of many tropical countries. Cooked tannia tubers are more nutritious than *taro*, but it is rather difficult to digest because of its larger starch grains. Tannia must be thoroughly cooked as some varieties contain high levels of calcium oxalate crystals in the leaves and tubers. The main corms usually contain oxalic acid and for this reason usually only the cormels are eaten which do not contain much of this acid. The cormels can be eaten as boiled, baked, parboiled and as oil-fried. The tubers must be boiled for about 15 min in water (sometimes with baking soda added), the water discarded, rinsed, and boiled again in fresh water to rid the tuber of its toxins.

Botany

Tannia [*Xanthosoma sagittifolium* (L.) Schott] belongs to the family Araceae and the genus *Xanthosoma*. It is an herbaceous perennial species of tropical flowering plant which produces an edible, starchy tuber. It has a corm or main underground stem in the form of a rhizome from which swollen secondary shoots, or cormels, sprout. Several large leaves also sprout from the main stem, which are sagittate and erect with long, ribbed petioles; the big leaves are light green and arrow-shaped with long petioles; inflorescences sprout between the leaves in a spadix, with a white 12–15 cm spathe which closes at its base in the form of a spherical chamber and opens at the top into a concave lamina; the spadix is cylindrical, slightly longer than the spathe, with female flowers on the lower portion, male flowers on the upper portion and sterile flowers in the middle portion. The spadices are rarely fertile and produce few viable seeds. The growth cycle lasts from 9–11 months: during the first six months the corms and leaves develop; in the last four months, the foliage remains stable and, when it begins to dry, the plants are ready for the cormels to be harvested. This perennial can grow up to 270 cm tall; however in dry climates with low humidity they do not grow that tall.

The taxonomy of tannia is unclear and in recent years, the tendency has been to give the name of *Xanthosoma sagittifolium* to all cultivated *Xanthosoma* species,

although a number of edible species in this genus have been recognised. The genus is divided into species mainly based on colour of corm, cormels and leaves and on the shape of the cormels. Among this, *Xanthosoma sagittifolium* (L.) Schott is the most widely grown and this has a chromsome number of 2n = 26. Other species include *X. atrovirens* Koch and Bouche, with yellow tubers and is favoured in Puerto Rico and Dominica. *X. violaceum* Schott (*X.nigrum*) is a species with a large plant canopy having violet coloured lamina and is grown occasionally in the Pacific islands but have little value as food. *X. brasiliense* (Desf.) is a small species cultivated solely for its edible leaves.

Cultivars

A large number of local cultivars are grown in India. There are no specific released varieties of tannia in India. Only local selections with low acridity, good texture and suitability of leaves for making rolls are available. Where corms and cormels yields are being preferred, local collections with high yield and less acridity are desired. For making rolls, cultivars with high leaf yield and less acridity are preferred.

Climate and soil

Tannia are plants of tropical rain forest regions which require high rainfall and adequate soil moisture Tannia is cultivated in tropical and subtropical zones between latitudes 30º N and 15º S and from 1350–1500 m above mean sea level and over a fairly wide range of temperature ranging from 13- 29°C. The crop is suited to high rainfall areas receiving an annual precipitation of 140–200 cm, but it can also grow well with an annual rainfall as low as 100 cm, provided it is evenly distributed. Tannia can be grown as an upland crop under irrigation and certain early maturing cultivars can be grown without irrigation in comparatively dry situations such as exposed steep slopes. Tannia requires well drained soil for optimum growth and cannot withstand waterlogging. Among the aroids, tannia is relatively more tolerant to dry conditions but performs better under irrigation especially when rainfall is irregular and experiments revealed that furrow irrigation usually resulted in better growth and yield. Tannia can be grown on a wide variety of soils except hard clay or pure sands. But for optimum yields, they require a deep well drained, nutrient rich soil, preferably with a soil pH ranging from 5.5 to 6.5.

In most of the situations, tannia is grown as a pure crop or as an intercrop in coconut gardens in uplands or with nendran banana along with cassava, cowpea, vegetables and ginger under lowland situations of Kerala.

Cultural requirements

Planting time: Optimal planting periods have been determined for tannia in relation to local climatic conditions like rainfall pattern, cultivar and its duration, growth cycle, drought tolerance and cropping systems in order to produce optimal yields and good quality tubers. In Kerala and Tamil Nadu, tannia is grown throughout the year provided there is irrigation and it is usually given weekly once.

Planting material: The planting material most commonly used are portions of the central corm, from 100–150 g, with three or four buds. They give greater yields than the cormels which are also sometimes used. One month old sprouted plants raised in nurseries can also be used.

Land preparation and planting: As in the case of other tuber crops, the land should be made to a fine tilth for proper tuberization. Ploughing to a depth of 20–40 cm followed by the formation of ridges and furrows can improve the growth and production of tubers especially in heavy textured soils. Application of FYM or compost @ 12.5 tonnes/ha is recommended and is usually applied at the time of land preparation. Planting on ridges or hills is recommended since tuber formation is improved with adequate drainage.

The spacing varies from 0.6 m × 0.6 m to 1.8 m × 1.8 m though the spacing had no significant effect on the number of cormels per plant, corm yield or size of the corm. A spacing of 60 cm × 60 cm or 75 cm × 75 cm can be adopted. The furrows are irrigated 2 days before planting. Corm pieces or cormels are planted in the main field at a spacing of 60 cm × 60 cm or 75 cm × 75 cm. A light irrigation is given after planting.

Intercultural operations

Little attention is given to the crop after planting, apart from occasional weeding and earthing up of the plants which influences the crop yield. NPK @ 80:50:100 kg/ha is recommended with split application of half the quantities of N and K and full dose of P within a week after sprouting. The remaining dose of N and K fertilizers are applied as top dressing one month after the first application and earthing up of plants is done. The first six months is a critical period for weed control. Ploughing and raking helps considerably in controlling weeds. Irrigation is given whenever it is required depending up on the weather conditions.

Pest and disease management

The most serious disease of tannia is ‘leaf burning disease’ or ‘root rot disease’. The above ground symptoms of the disease are associated with rotting roots hence the descriptions for this disease indicate that the outer leaves of the plant gradually go yellow from margin to mid-rib and finally the leaf dies. The roots of the plant also die. Plant growth is stunted. The diseased plant reportedly has no healthy roots. Production of marketable cormels is severely affected. The causative agent of this disease is reported to be *Pythium myriotylum*. Main sources of the innoculum are infected soil and infected planting material. The development of the disease is helped by poorly drained soils. To control this disease use disease free planting material.

Harvesting and yield

Tannia tubers (cormels) are ready for harvest when the leaves begin to senesce (physiological maturity). Harvesting of the crop is usually done during ninth to eleventh month after planting. Soil is dug away from the plant and the cormels are separated from the mother corm which is covered up with soil and left to produce a new crop. In this way the plant may continue to grow for several years.

The mature cormels do not deteriorate, if left in the ground during the dry season and they are often harvested as and when required. If mature cormels are not harvested, most of them will sprout in rain, become watery and thus less suitable for consumption.

The commercial product is washed, dried and disinfected carefully before being placed in boxes in cold-storage rooms. The harvested tubers should be peeled and can be kept at room temperature for several weeks; if refrigerated, this can be longer. In small plantations, harvesting of the cormels begins four to six months after planting and is done without uprooting the plant. It gives an yield of 500 to 600q/ha.

COLEUS POTATO

The coleus potato *Plectranthus rotundifolius* is believed to have originated in central or east Africa, but was early spread throughout tropical Africa and into south-east Asia, including India, Sri Lanka, Malaysia and Indonesia, where it is cultivated on a small-scale. The Arabs are thought to have introduced this into India. From India the Portuguese introduced it into Malaysia and Indonesia. Common names of coleus potato are coleus, Chinese potato, Zulu potato, Sudan potato, Indian potato, Livingstone potato, African potato. It produces handsome tubers which resemble the Chinese artichoke, but have yellow skin and white flesh. They are also dried and then ground to make a flour for dumplings. The tubers can be used as a potato substitute and are usually cooked in a curry and eaten with rice, but they can also be boiled, baked or fried similarly to potato chips. In Africa, the coleus potato is sometimes used in the treatment of dysentery and in the treatment of certain eye disorders. The 100 g edible portion of the tubers contains water 75%; protein 1.4%; fat 0.5%; carbohydrate 21%; fibre 0.7%; ash 1%; calcium 17 mg; iron 6 mg; thiamine 0.05 mg; riboflavin 0.02 mg; niacin 1 mg; ascorbic acid 1 mg. The principal amino acids in the protein are arginine, aspartic and glutamic acids.

Although formerly of considerable importance as a staple foodstuff in tropical Africa, the coleus potato has been largely replaced by other starchy foodstuffs, such as cassava and potatoes, and production has declined to such an extent that it has almost disappeared in many areas.

Botany

Coleus potato (*Plectranthus rotundifolius*) belongs to the family Lamiaceae and the genus *Plectranlhus.* It is a small, herbaceous annual, 15–30 cm high, prostrate or ascending, with a succulent stem and somewhat thick leaves having an aromatic smell resembling that of mint. Flowers are small, pale violet, produced on an elongated terminal raceme. Small dark brown tubers are produced in clusters at the base of the stem. They are primarily perennial herbs or sub-shrubs with opposite leaves. The flowers, which are blue or lilac, small, and verticillastrate, are gathered into compound inflorescences. There are approximately 150 species, distributed in the tropics of the eastern hemisphere. Some species, such as *Coleus parviflorus* and *C. edulis,* have starchy tubers and are cultivated for food in tropical Africa and Asia.

Improved cultivars

Sree Dhara: This is the first with good cooking quality developed by CTCRI, Thiruvanthapuram with 5 months duration.

Nidhi: This variety is released from RARS, Pattambi with 5 months duration.

Suphala: This is a tissue culture mutant derived by Kerala Agricultural University from local cultivar suited for year round cultivation with a duration of 120 to 140 days.

CO 1: This is a clonal selection from local type introduced from Tenkasi by TNAU, Coimbatore. It yields 319 q/ha in crop duration of 180–190 days. The tubers have 21.5% starch. The cooked tubers are tasty and have lesser soil odor.

Climate and soil

The plant is suited to high rainfall areas; evenly-distributed rainfall and low night temperatures favour the development of tubers. It is grown in India as a monsoon crop and is sometimes grown under irrigation. Optimum yields are obtained on well drained, sandy loam soils; heavy clay soils are unsuitable. The plant cannot stand waterlogging and is usually grown on ridges, except in very well drained soils. Waterlogging causes deformities to the tubers and reduces yields considerably.

Cultural requirements

Planting time: March – April is the best season for planting.

Planting material: It is generally propagated by suckers obtained from germinating tubers. Harvest the tubers in January and store under room temperature for two months. Prepare raised nursery beds in March – April or May-June. Small tubers of 5–10 g in wight are selected and dibbled in the nursery beds with a spacing of 5 cm × 15 cm and about 4 cm deep. 200 kg seed tubers (500 tubers) are required, which will produce enough suckers to plant one hectare.

Raise the nursery approximately one month before planting. An area of 500–600 m^2 is sufficient to produce cuttings required for one ha of main field. Apply 125–150 kg farmyard manure in the nursery area. Plant the seed tubers at a spacing of 15 cm on the ridges taken 30 cm apart. About 170–200 kg of tubers is required to raise the nursery. Take the vine cuttings to a length of 10–15 cm from the top portion after three weeks from planting.

Land preparation and planting: Prepare the main field by ploughing and harrowing and bring it to a fine tilth. Broadcast 25 tonne/ha of farmyard manure at the land preparation. Form ridges and furrows at 60 cm apart. Apply 30 kg N, 60 kg P and 50 kg K/ha in the furrows and cover with soil. Irrigate the furrows 2 days before planting the suckers/cuttings. The cuttings taken from the nursery beds are planted at a spacing of 30 cm. Use terminal herbaceous cuttings of 10 to 15 cm length taken from the nursery beds (30–40 days after planting) and plant them in the main field during July-August. Irrigate the field soon after planting.

Intercultural operations

Irrigation is done at weekly intervals. Earthing up is to be done 30 days after

planting. Apply 30 kg N and 50 kg K/ha 45 days after planting as top dressing. Earthing up can be done once again.

Pest and disease management

The coleus potato is relatively free from pests and diseases though *Pycnarmon cribrata, Phostria piasusalis* and a leaf folder, *Hymenia recurvalis*, have been reported from India as being important. These have been controlled by spraying with pesticides such as dimethoate. Deep ploughing of the field in summer, adopting crop rotation and destroying root residues and other plant parts by burning, the root knot nematode can be controlled. To control sucking pests, Roger @ 1 ml/litre of water can be sprayed.

Harvesting and yield

The crop normally reaches maturity in 6 to 8 months in India. The tubers are ready for harvesting when the leaves begin to wither, and are normally dug by hand. Harvesting cannot be delayed as the mature tubers deteriorate rapidly, if left in the soil, but they can be stored successfully in dry sand or in a cool, well ventilated shed. The tubers resemble the potato, but are smaller, with an aromatic sweet flavour. Yields normally range from 70 to 150 q/ha, although under very favourable conditions they may reach 180–200 q/ha. Total duration of the crop, including the nursery is 150–180 days.

GINGER

Fig. 21. Ginger

Ginger, *Zingiber officinale*, probably originated from South Asia, India and China, but now cultivated and is available all over the world. It has been used in China for over 2,500 years. It is cultivated on commercial-scale in India, Hawaii, and Nigeria and exported to many other countries. Ginger has been cultivated in tropical Asia from ancient times and is now-a-days throughout the tropics. The Greek and Romans knew of it not later than the first century AD. In Hindi it is known as *ada, ale, adrak*. The name ginger comes from the Sanskrit word 'sinabera' meaning 'shaped like a horn' because of its resemblance to an antler.

It is an indispensable ingredient in Indian cooking. The rhizomes of ginger are sold fresh; sliced and pickled in vinegar; or preserved in syrup. It has been an important spice for over 3,000 years and is an essential ingredient of Eastern dishes. Chinese called it a 'universal medicine ' and used it in medicine for a variety of ailments like digestive complaints, coughs, colds, diarrhoea, nausea and bloating.

Botany

Ginger (*Zingiber officinale* Roscoe) belongs to the family Zingiberaceae and the genus *Zingiber.* It is a biennial or perennial reed-like herb, grown for the pungent, spicy underground stems or rhizomes. The stems reach a height of 3 feet, with lanceolate, smooth leaves up to 8 inches long. The plants are propagated by small divisions of the rhizomes. Ginger consists of three parts, namely, rhizomes, flowers and fruits. Rhizome is knobbly and fleshy that is covered in rings. This part is used in food and medicine. Rhizomes grow underground but they are not roots but stem. Purple Flowers grow directly from the rhizomes and are generally 30 cm long. Fruits of ginger are red and have three chambers with number of small seeds. There are several races. The plant rarely flowers and vegetative propagation is necessary. The knobby, odd-shaped rhizomes have a peppery, slightly sweet flavor and pungent, spicy aroma. Colour of the skin ranges from greenish-yellow to ivory white. It may contain fibres depending on the age or maturity of rhizomes and variety grown.

Climate and soil

Ginger is a tropical plant adapted for cultivation even in regions of sub-tropical climate such as the high ranges. It is extensively cultivated in the alluvial lands. For successful cultivation a rich well-drained soil is essential, otherwise the ginger will be too 'hot'. It prefers a rich soil with high humus content. Being an exhausting crop, ginger is not cultivated continuously in the same field but shifting cultivation is practised. The crop cannot withstand waterlogging and hence soils with good drainage are preferred for its cultivation. It is a shade tolerant or shade loving crop with shallow roots and therefore suitable for intercropping and as a component in the homesteads where low to medium shade is available.

Improved cultivars

Suravi: This variety, released by Orissa University of Agriculture and Technology, Pottangi, Odisha. It matures within 225 days. Fingers cylindrical rhizomes dark grazy skin, fibre 4%, oil 2.1%, oleoresin 10.2%. The fresh mean yield is 176 q/ha.

Suruchi: This variety released by Orissa University of Agriculture and Technology, Pottangi, Odisha. It matures within 218 days. Rhizome greenish yellow, fibre 3.8%, oil 2.0%, oleoresins 10%. The fresh mean yield is 116 q/ha.

Suprabha: This variety, released by Orissa University of Agriculture and Technology, Pottangi, Odisha. It matures within 229 days. Profuse tillering, plumpy fingers, bright grey skin, fibre 4.4%, oil 1.9%, oleoresin 8.9%. The fresh mean yield is 166 q/ha.

IISR- Varada: This variety, released by IISR, Kozhikode, Kerala, yields, 226 q/ha.

IISR Mahima: This variety, released by IISR, Kozhikode, Kerala, yields, 232 q/ha.

IISR Rejatha: This variety released by IISR, Kozhikode, Kerala, yields is 224 q/ha.

Himagiri: This variety, released by Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh, yield is 135 q/ha.

Cultural requirements

Planting time: The best time for planting ginger is during the first fortnight of April, after receipt of pre-monsoon showers. For irrigated ginger, the best suited time for planting is middle of February (for vegetable ginger).

Planting material: Ginger rhizomes are used for planting. For selection and preservation of planting material, the following method may be adopted:

Mark healthy and disease free plants in the field when the crop is 6–8 months old and still green. Select best rhizomes free from pest and disease from the marked plants. Handle seed rhizomes carefully to avoid damage to buds. Soak the selected rhizomes for 30 min. in a solution of mancozeb (0.3%) and malathion (0.1%). Dry the treated rhizomes in shade by spreading on the floor. Store the treated rhizomes in pits dug under shade, the floor of which is lined with sand or saw dust. It is advisable to spread layers of leaves of *Ban nimbu* or *Panal* (*Glycosmis pentaphylla*). Cover the pits with coconut fronds. Examine the stored rhizomes at monthly intervals and remove the rhizomes that show signs of rotting. This will help keep the inoculum level low. Provide one or two holes for better aeration. Treat the seed rhizomes similarly before planting also. The 1500 kg/ha of seed rhizomes is required.

Land preparation and planting: Clear the field during February-March and remove the weeds, stubbles, roots etc. Prepare the land by ploughing or digging. Apply 25 tonne/ha of farmyard manure at the land preparation.

Prepare broad raised beds of convenient length (across the slope where the land is undulating), 1 m wide, 25 cm high with 40 cm spacing between the beds. Provide drainage channels, one for every 25 beds on flat lands. A fertilizer dose of 75 kg N, 50 kg P and 50 kg K/ha are required. 50 kg P and 25 kg K/ha is applied as basal dose at the planting. Then irrigate the beds 2 days before planting.

Plant rhizome bits of 15 g weight in small pits at a spacing of 20 cm × 20 cm or 25 cm × 25 cm and to a depth of 4–5 cm with at least one viable healthy bud facing upwards. Soon after planting irrigate the field lightly.

Intercultural operations

Immediately after planting, mulch the beds thickly with green leaves @ 15 tonne/ha. Repeat mulching with green leaves twice @ 7.5 tonne/ha first 44–60 days and second 90–120 days after planting. Grow green manure crops like ha and sunnhemp in the interspaces of beds, along with ginger and harvest the green manure crop during second mulching of ginger beds. Irrigate the crop at 8–10 days interval.

Half the quantity of N (i.e. 37.5 kg N/ha) is applied 60 days after planting. The remaining quantity of N (37.5 kg) and K (25 kg) is applied 120 days after planting. Remove weeds by hand weeding before each mulching. Repeat weeding according to weed growth during the fifth and sixth month after planting. Earth up the crop during the first mulching and avoid water stagnation.

Pest and disease management

Diseases

Rhizome rot: For control of rhizome rot adopt the following measures:

(i) Select sites having proper drainage.
(ii) Select seed rhizomes from disease free areas.
(iii) Treat seed rhizomes with 0.3% mancozeb.
(iv) When incidence of rhizome rot is noted in the field, dig out the affected plants and drench the beds with 1% Bordeaux mixture or 0.3% mancozeb.

Leaf spot: For controlling the leaf spot disease, 1% Bordeaux mixture or 0.3% mancozeb may be sprayed.

Insect pests

Nematode: For control of nematode in endemic area, apply neem cake @ 1 tonne/ha at planting and carbofuran 1 kg ai/ha at 45 days after planting.

Shoot borer (Conogethes punctiferalis): It is the most serious pest of ginger. The shoot borer can be managed by spraying malathion (0.1%) at 21-day intervals from July to October.

Rhizome scale (Aspidiella hartii): It infests rhizomes in the field (at later stages) and in storage. Adult (female) scales are circular (about 1 mm dia) and light brown to grey and appear as encrustations on the rhizomes. They feed on sap and when the rhizomes are severely infested, they become shriveled and desiccated affecting its germination. The pest can be managed by treating the seed material with quinalphos (0.075%) (for 20–30 min) before storage and also before sowing in the infestation persists. Severely infested rhizomes are to be discarded before storage.

Leaf roller (Udaspes folus): Larvae cut and fold leaves and feed from within. The adults are medium-sized butterflies with brownish black wings with white spots; the larvae are dark green. A spray with carbaryl (0.1%) or dimethoate (0.05%) may be undertaken when the infestation is severe.

Root grubs: They occasionally feed on tender rhizomes, roots and base of pseudostems causing yellowing and wilting of shoots. The pest can be controlled by drenching the soil with chloropyriphos (0.075%).

Harvesting and yield

For vegetable ginger, the crop can be harvested from sixth month onwards. For dry ginger, harvest the crop between 8 and 9 months. After harvest, the fibrous roots attached to the rhizomes are trimmed off and soil is removed by washing. Rhizomes are soaked in water overnight and then cleaned. The skin is removed by scrapping with sharp bamboo splits or such other materials. Never use metallic substances since they will discolour the rhizomes. After scrapping, the rhizomes are sun-dried for a week with frequent turnings. They are again well rubbed by hand to remove any outer skin. This is the unbleached ginger of commerce. The peeled rhizomes are repeatedly immersed in lime solution (2%) and allowed to dry in the sun for 10 days while rhizomes receive a uniform coating of lime. This is the bleached ginger of commerce. A rhizome yield of 150–200 q/ha of green/ fresh ginger can be harvested. ●

CHAPTER 19

Leafy vegetables

LEAFY vegetables, potherbs and greens are very rich in minerals and vitamins A and C. They also supply the roughage required in the daily diet. Amongst all the vegetables, the leafy vegetables have a very high protective food value. They are rich in minerals and hence are called as 'mines of minerals'. Vitamin A and C are present in abundant quantities. Beside this, soft fibrous matter present provides necessary roughage in diet. The dieticians recommend daily consumption of at least 116 of leafy vegetables for a balanced diet. A variety of greens is cultivated in India. The leaves of certain plants which grow wild are also used as vegetable. Some of the vegetables like cabbage, Chinese cabbage and kale considered in other groups may also be considered as green leafy vegetables. The leaves of some shrubs and trees are used as potherbs or greens. The leafy vegetables are grown throughout the year. Some are suitable for growing during winter months such as spinach beet, spinach, fenugreek, mustard greens. Others like amaranth, *kulfa*, *poi*, are suitable for growing during summer. The leafy crops include spinach beet, spinach, Indian spinach, amaranth, fenugreek, mustard greens, coriander leaves and mint/*pudina*.

SPINACH BEET

Spinach beet is a native of Indochinese region. It is also known as beet leaf, desi palak, common palak, palak. Spinach beet is a commonly grown leafy vegetable throughout the tropical and subtropical regions. It is commonly grown in Uttar Pradesh, West Bengal, Punjab, Haryana, Delhi, Madhya Pradesh, Bihar, Maharashtra and Gujarat.

The tender leaves are harvested along with petiole and cooked as vegetable. Spinach beet (*Beta vulgaris* L. var. *bengalensis* Roxb.) is different from Spinach (*spinacia oleracea* L.). Spinach beet/*palak* has leaves with entire margin and it produces bisexual flowers. Spinach beet can tolerate high temperature and grows well in hot weather. This is popular in northern states,

Spinach/*vilayati* palak has leaves with lobed leaf margin and the plants produce three types of flowers, viz. staminate, pistillate and hermophrodite. Spinach is purely a cool season crop and cannot tolerate high temperature. This is popular in southern states. Leaves of spinach beet are rich sources of vitamin A (9770 IU/ 100 g), calcium (380 mg,/100 g), iron (16.2 mg/100 g), protein (3.4%) and carbohydrates (6.5%).

Botany

Spinach beet is closely related to beet root and Swiss chard. Botanically it is known as *Beta vulgaris* L. var. *bengalensis* Hort. This belongs to the family Amaranthaceae (formerly Chenopodiaceae). It is a herbaceous annual for the edible leaf production, while it is biennial for the seed production. In the early stages of the plant growth (at vegetative phase), it produces rosette, succulent edible leaves on a small thick stem. Later, at reproductive phase the stem elongates after about 75 days of sowing which results in bolting. Plant has taproot system along with more number of feeder roots. Leaves are long with entire margin and long petioles. The inflorescence is a racemose with bracts of cymose type and emerges either in the axils of the leaf or from a spurious terminal bud from the main shoot as well as from the lateral shoots. Flowers are small, sessile, bisexual (hermaphrodite) perfect, bracteates (leafy) and are borne in the axils of leaf in a group of 2–3, with 5 stamens opposite to perianth lobes on a fleshy disc within unilocular perigynous ovary. Flowers produce abundant, small and light pollen grains which are carried by wind leading to wind pollination. Hence the crop is highly cross-pollinated. The whole phase of flower bud development takes 35 days to come in bloom. There are 6 developmental stages through which each bud passes before it opens into a flower. The anthesis takes place between 7 AM to 5 PM with peak period between 11 AM to 1 PM. The flowers open mostly during mid-day. In an individual flower, anthesis is completed within 2 hours and hastened by high temperature and low humidity. Stigma receptivity begins 8 hours before anthesis, reaches the maximum just after anthessis and continues for another 10 hours. The fruit is actually a seed ball containing 2–3 seeds (Pandita and Lal, 1990).

The differences between spinach beet, spinach and beet root are as under:

Spinach beet

1. The botanical name of spinach beet is *Beta vulgaris* L. var. *bengalensis* Roxb. [synon: *B. v.* ssp. *vulgaris* convar. *cicla*/*B. v.* ssp. *v.* convar. *cicla.* var. *cicla].* This belongs to the family Amaranthaceae (formerly Chenopodiaceae). The common names of spinach beet are, beet greens, beet leaf, desi palak, common palak, and palak.
2. Spinach beet is closely related to beet root and chard.
3. It is commonly grown in Uttar Pradesh, West Bengal, Punjab, Haryana, Delhi, Madhya Pradesh, Bihar, Maharashtra and Gujarat. This is popular in northern states,
4. Leaves are succulent and long with entire margin and long petioles. This is widely cultivated for its tender leaves with petioles, which are usually cooked like spinach.
5. Spinach beet can tolerate high temperature and grows well in hot weather. It is a winter season crop in the plains of India. It can withstand frost better than other vegetables. It can also tolerate warm weather but relatively hot weather will result in quick bolting making the plant unfit for producing edible leaves.
6. The flowers are small, sessile, bisexual (hermaphrodite) perfect. Highly cross pollinated and wind pollinated. Stigma remains receptive up to 10

hours after anthesis.

7. Spinach beet is a herbaceous annual for the edible leaf production, while it is biennial for the seed production. In the early stages of the plant growth (at vegetative phase), it produces rosette, succulent edible leaves on a small thick stem. It produces seeds freely in the tropical plains. The seed is monogerm in spinach beet.
8. The fruit is actually a seed ball containing 2–3 seeds.
9. The diploid chromosome number is 2n=18, like beet root and chard which indicates their close relationship.

Spinach

1. The botanical name of spinach is *Spinacia oleracea* L. It belongs to the family Amaranthaceae (formerly Chenopodiaceae). The common names of spinach are common spinach and *Vilayati palak.*
2. Spinach is grown all over the plains. It is popular in the southern states also.
3. It is strictly a winter season crop and withstands freezing weather better than other crops and does not grow well during hot weather.
4. It is an herbaceous annual plant for leaf production and behaves as a biennial for seed production. Spinach has leaves with lobed margin. The edible part of the spinach is a compact rosette of leaves. Leaves vary in shape, thickness and are smooth or savoyed/wrinkled depending on the cultivar.
5. The flowers are dioecious (individual flowers are either male or female, but only one sex is to be found on any one plant so both male and female plants must be grown if seed is required) and are pollinated by wind.The plant is not self fertile.
6. But monoecious plants are also rarely located.
7. Flowers are small, greenish, axillary and borne in clusters. Flowers may be staminate, pistillate or hermaphrodite. Unpollinated pistillate flowers remain receptive for 2–3 weeks.
8. The seed is multigerm in spinach. A multigerm seed is a seed which occurs as a cluster of seeds fused together and which produces more than one plant when it germinates. The multiple plants must be reduced to one by a process called 'singling'.
9. The diploid chromosome number is 2n=12.

Beet root

1. The botanical name of beet root is *Beta vulgaris* L. var. *vulgaris.* [synonn: *B. v.* ssp. *v.* convar. *vulgaris* var. *vulgaris; Beta vulgaris* var *crassa*]. It belongs to the family Amaranthaceae (formerly Chenopodiaceae). It is related to sugar beet [*B. v.* ssp. *v.* convar. *vulgaris* var. *altissima*], which is a major commercial crop due to its high concentrations of sucrose, which is extracted to produce table sugar. The common names of beet root are, table beet, blood turnip, red beet, garden beet, beet, and *chukandar.*
2. The roots of beet root are used as vegetable. It is primarily a cool season crop but grows well in warm weather and hence can be grown during winter

all over the plains.

3. Flowers are small, sessile, bisexual, perfect and are borne in the axils of leaves in a group of 2–3, with 5 stamens, flowers produce abundant, small and light pollen grains which are carried by wind. Hence the crop is highly cross pollinated (a wind pollinated crop).
4. It behaves as a biennial, producing a thickened root and a rosette of leaves first year, and flowers and seeds second year. Since it is a temperate type of crop it is only grown for edible roots in the plains and for seeds in the hills where temperate climate prevails.
5. Each 'seed' is botanically a berry, and contains several actual seeds (multigerm seeds; 2–6 seeds) (breaking them apart would damage many of the seeds). The true seeds are small, kidney shaped and brown. The ovary forms a fruit which is embedded in the base of the perianth of the flower. Each fruit contains a single seed whose shape varies from round to kidney shaped. The ovaries are enclosed by the common receptacle of the flower cluster. A monogerm seed is formed when a flower occurs singly. The multigerm beet seed is formed by an aggregation of two or more flowers. Monogerm varieties can be precision drilled but multigerm varieties have to be singled. A typical beet seed is a fruit that can contain 2–3 embryos, which results in clumping. Monogerm beet seeds contain only one embryo. This feature eliminates thinning and results in superior uniformity.
6. The diploid chromosome number is 2n=18

Breeding

Spinach beet is a cross pollinated crop and hence methods employed for the improvement of cross-pollinated crops can be adopted for this crop also. The basic methods employed are introduction, selection and hybridization.

Introduction is useful in the initial stages of a breeding programme. It is the easiest and quickest method of crop improvement. Some cultivars in spinach are introductions.

Mass selection is currently used in cross-pollinated crops like spinach beet for crop improvement and maintenance of cultivars. The best individual plants are selected in the population on the basis of phenotypic performance and their seeds composited for raising the subsequent generations. Large number of plants are selected in order to avoid inbreeding depression. It is very effective for improving qualitative or highly heritable characters but not very useful for improvement of polygenic characters like yield, particularly if it has low heritability. The cultivar HS-233 has been developed by mass selection.

In hybridization method, desirable recombinants are selected in the segregating population of crosses involving two or more parents. Pedigree method or bulk population method is employed for the selection but former is mostly used in spinach beet. Several cultivars have been developed by this method. Pusa Palak, has been developed from the cross Swiss chard × local *palak*; Pusa Harit from the cross sugar beet × local *palak.*

Both natural and artificial mutations have also been exploited for the development of cultivars in spinach beet. Jobner Green has been developed as a

result of spontaneous mutation in local material.

Selfing is very important to maintain the purity of progeny after selection or hybridization. For selfing, the entire plant or few branches are enclosed in a thick muslin cloth bag so that pollen does not get blown outside or foreign pollen does not pollinate the flowers. The bag should be shaken once or twice a day to ensure better set. The bags must not be opened in windy days (Pandita and Lal, 1990).

It is a wind cross pollinated crop. Efforts were made at IARI, New Delhi to evolve high yielding varieties, which resulted in the new varieties like 'All Green'and 'Pusa Jyoti'. At the University of Udaipur, a high yielding variety 'Jobner Green' suited to alkaline soil condition was evolved. Similarly, HS 23 has been developed by HAU, Hisar. The improved varieties developed by selection from local types, by hybridization between palak and sugarbeet, Swiss chard or beet root and colchicine induced polyploidy are available (Nath *et al.* 2002).

Improved Cultivars

Pusa Bharati: Developed by IARI, New Delhi. Leaves 25 cm long and 14 cm in breadth, smooth, tender, pure green with out red pigmentation. Can also be grown during *kharif* and summer seasons; performs best in winter and early spring seasons. Has high nutritive value. Maturity 30–40 days. Yield 500 q/ha.

Pusa Jyoti: Developed by IARI, New Delhi. A giant leafed variety. It produces large, green, thick, tender, succulent leaves, good taste when eaten raw as salad. Plants very vigorous, quick growing, regenerate quickly after each cutting. Gives 6–8 cuttings. Rich in calcium, iron and ascorbic acid. Can be grown through out the year. Maturity 40 days. Yield 490 q/ha.

Pusa Harit: Developed by IARI, New Delhi. Suited for hills. Plants upright, vigorous, uniformly thick, green, slightly crinkled, big sized leaves. Heavy yielder. Late bolting habit. Has a wide range of adaptability to varying climates. Tolerate alkaline soils. Maturity 35–40 days. Yield 425 q/ha.

Pusa All Green: Developed by IARI, New Delhi. It produces uniformly green, medium sized, tender leaves. As a winter crop, it gives about 6–7 cuttings at 15–20 days interval. Maturity 40 days. Yield 125 q/ha of green material.

Pusa Palak: Developed by IARI New Delhi.Hybridization between Swiss chard × Local Palak. Leaves uniform green with red pigmentation, late bolting.

Arka Anupama: Developed by IIHR, Bangalore. Late bolting variety with medium large, thick, dark green leaves. It has got excellent cooking quality and it is rich in vitamins and minerals. Four cuttings can be taken over a period of 65–70 days. It is resistant to *Cercospora* leaf spot under epiphytotic condition. Yield 410 q/ha.

Jobner Green: Developed by University of Udaipur, Jobner. Produces uniform green, large, thick, succulent tender leaves, with strong flavour. Maturity 40–45 days. Yield 300 q/ha.

Pant Composite: Developed GBPUAT, Pantnagar. Composite variety. Leaves green, high yielding, tolerant to *Cercospora* leaf spot. Yield 275 q/ha.

Punjab Selection: Developed by PAU, Ludhiana. Seletion from local type. Leaves light green, thin, long narrow, smooth; stem with purple pigmentation. Yield 375 q/ha.

Punjab Green: Developed by PAU Ludhiana. Selection from local type. Yield 375 q/ha. Plants semi erect, leaves glossy, thick, long, succulent with low oxalic acid.

Palak No 51-16: Selection from local type. Leaves green, several cuttings, late bolting.

HS-3: Developed by HAU, Hisar. Selection from a local type. Leaves light green, medium sized, quick growing.

Climate and soil

It is a winter season crop in the plains of India. It can withstand frost better than other vegetables. It can also tolerate warm weather but relatively hot weather will result in quick bolting making the plant unfit for producing edible leaves. Swiss chard thrives in a comparatively cool climate and does best at a temperature range of 7–24°C. It is half-hardy and can withstand light frosts, although growth will be retarded at low temperatures. Prolonged exposure to temperatures less than 5°C will induce seed production (bolting), usually in spring. During hot weather, leaves remain small and are of inferior quality. In late summer, particularly, foliage of plants is subject to a fungal leaf spot which may be a production limiting factor, given climatic conditions conducive to its development. Swiss chard can be grown on a wide variety of soil types, provided they are well-drained, free of root knot nematodes, reasonably fertile and amply supplied with water. It does very well in sandy loam soil. Better results as regards quality and yield were obtained in the soil with pH 7, but the variety 'Jobner Green' gave excellent performance in soil with pH 7–10.5. The soil for this crop can be prepared by 3–4 ploughings, followed by leveling.

Cultural requirements

Sowing time: The main sowing season in the plains is from the last week of August to second week of November. In places with milder climate, it can be grown throughout the year. It is sown from March- May in hilly tracts.

Land preparation and sowing: Land is prepared into a fine tilth. 25 tonnes/ha of FYM should be mixed thoroughly in the soil at the time of field preparation. Sowing is usually done by broadcasting the seeds in the levelled plot. 25 kg N, 25 kg P, 50 kg K/ha as basal dose is applied before sowing. A light irrigation should be given 2 days before sowing. The crop is also direct sown in lines. Sowing is done in rows 30 cm apart and later on thinning to 7.5 cm within the row. Seeds should be placed at a depth of about 4 cm. The seed germinates in about 10 days if proper soil moisture and temperature are available. About 25 kg of seeds are required to sow one hectare area.

Intercultural operations

The plant has a moderately deep root system but, like other leafy vegetable crops, it should not be allowed to suffer moisture stress. It thus requires fairly frequent irrigation to ensure that the soil does not dry out to less than 50% available water. Soil moisture should never be limiting. In light soils, it is desirable to give irrigation soon after the sowing is complete, but in heavier soils the sowing should

be done when enough soil moisture is available. Subsequent irrigations during winter should be given at 6–7 days interval depending on the soil moisture availability. Regular hoeing and weeding should be done. The crop should be top dressed with 25 kg N/ha after first cutting. Earthing up is also to be done.

Pest and disease management

Diseases

Damping off: This disease is caused by the fungus *Pythium* sp. Seedlings are attacked by the fungus and killed. This disease can be controlled by treating seeds before sowing with captan at the rate of 2.5 g per kg of seeds.

Leaf spot: The leaf spot caused by the fungus *Cercospora beticola* Sacc., is the most important of two fungal foliage diseases affecting spinach beet. Brown dead circular spots are found on the diseased leaves. It can be particularly important from mid-summer to early autumn. The causal fungus is favoured more by interrupted wetting (heavy dew at night with dry days) than during continuously wet or dry periods. The optimal temperature range for fast development of leaf spots is between 25°C and 30°C. The leaf spots, which are light grey necrotic spots with a darker outline, also occur on other plants in the family, such as beet. Apart from quality loss because of cosmetic appearance, severe infection can result in death of leaves. It can be controlled by spraying chlorothalonil (0.2%) or mancozeb (0.2%) at 15 day interval. Sanitation and crop rotation are very important practices for control of this disease. At the end of cropping, infected debris should be destroyed by deep ploughing.

Insect pests

Aphids: These insects are small in size and found in large number on the tender portions of the plant. They suck the sap from the plant tissues causing plant to become weak. Aphids can be controlled by spraying malathion 50 EC (0.1%).

Leaf eating caterpillar: The caterpillars of *Laphygma exiqua* feed on leaves and make holes. They are also controlled by spraying malathion 50 EC (0.1%). Waiting period of 15 days before harvest after spraying should be observed.

Harvesting and yield

The crop becomes ready for first cutting after 35–40 days of sowing. The crop comes to first cutting three to four weeks after sowing. Only well grown green succulent and tender leaves should be cut or trimmed along with petiole. Winter crop gives more cuttings at the height of 5–7.5 cm above the ground. Subsequent cuttings can be done at the interval of 15–18 days depending on the variety. On an average, a total yield of about 80–100 quintals greens per hectare can be harvested from 4–6 cuttings.

The green leaves are very tender and succulent. After harvest the leaves cannot be stored for longer period and hence should be sent to the market. Before marketing leaves are tied in small bundles. All the weeds, diseased and broken leaves should be discarded at the time of bunching. Washing of the leaves is not desirable because it causes rotting and yellowing of the leaves in the

centre of the bundle. In the early morning the leaves are crisp and may break during harvesting.

Seed production

The cultural practices for seed production are similar to that for leaf production. The following aspects are to be considered while going for seed production:

Isolation: The Beet Family, Chenopodiaceae includes the following species:

Beta vulgaris: Spinach beet/beet leaf, beets, Swiss chard.

Chenopodium album: Lamb's quarters.

Chenopodium ambrosioides: Epazote.

Chenopodium giganteum: Magenta-centered lamb's quarters.

Chenopodium quinoa: Quinoa.

Spinacia oleracea: Spinach.

Wind pollinated members of the Beet Family have very light pollen and need up to 3–8 km for safe distance isolation. Swiss chard and beets are in the same species (*Betula vulgaris*) and must be isolated from each other or they will cross. Different Beet Family species will not cross pollinate, so that one beet or one chard, one quinoa (*Chenopodium quinoa*), one red (*Chenopodium giganteum*) and one white (*C. alba*) lamb's quarters, one orach (*Atriplex hortensis*) and one spinach (*Spinacia oleracea*) can all be grown together without danger of crossing. Beets, chard, orach and spinach will not pollinate themselves. Spinach beet is a wind cross pollinated crop and the two varieties should be kept about 1600 m apart to produce pure seeds. Usually the plants are left to produce stalks after two to three cuttings are taken.

Thinning and roguing: Thinning and roguing is to be done several times. Thinning will start as the leaves of seedlings start touching each other and continue till the plant to plant distances stands at about 15–20 cm. Before bolting, thinning and roguing for off types will include plants in terms of colour of plants, shape of leaves, stoutness in establishment etc. Early bolters should be removed as soon as observed. Land should be kept clean through weeding and mulching. Plants of *Chenopodium album* must not be allowed to grow in and around the field. Irrigation is to be provided as and when required.

Harvesting of seeds and seed yield: Spinach beet produces seeds in about 80–90 days after sowing. The seeds mature in sequence even in the same plant. First opened inflorescence seeds mature first. Seeds after maturation may get discoloured or damaged due to foggy weather or rain. As such sequential harvesting should be done. When the seed stalks and seeds turn yellow and dry, harvesting is to be done by cutting the branches. About 2–3 harvests will be necessary before leaving the crop for seed production. Harvested branches should not be kept heaped, which may cause damage to seed due to fermentation. Harvested branches are to be dried in the sun over drying floor or canvas. Threshing is done by hand, beating with a stick after being properly dried. The fruit balls, each of which contains 2–3 seeds, are collected after threshing, winnowing and cleaning. Seeds are dried to 9% seed moisture content for temporary open storage. Seed yield is about 600 kg/ha. The seeds remain viable for 3–4 years under proper storage conditions.

SPINACH

Spinach is probably originated in South-West Asia and was used in Iran over 2000 years ago. It was brought to Spain in 1000 AD. and taken to America by the early colonists. According to Ahuja *et al*. (2010), spinach (*Spinacia oleracea* L.) is thought to have originated in Persia (Iran). It made its way to China in 7th century. It has a much more recent history in Europe. It has been cultivated throughout the world and used for centuries. In Hindi it is known as *vilayati palak.* The edible part of the spinach is a compact rosette of leaves. Spinach or *Vilayati palak* is grown all over the plains. It is popular in the southern states also.

Spinach is a leading and excellent source of vitamin K (about 400% of D.A), vitamin A, manganese, folate (B9), magnesium, iron, vitamin C, riboflavin (B2), calcium, potassium, and pyridoxine (B6). Spinach is also a very good source of dietary fibre, copper, thiamin (B1), phosphorus, zinc and vitamin E. It is also a good source of omega-3 fatty acids, niacin (B3), and trace mineral selenium.Vitamin K is important for functions of several proteins in the body. It helps clotting of blood after an injury, makes bones dense and less fragile. Vitamin K is a part of the chlorophyll, so generously contained in leafy green vegetables. Spinach is one of the richest sources of yellow and orange carotenoids, called lutein and zeaxanthin. Both lutein and zeaxanthin decrease risk of macular degeneration - a leading cause of blindness in elderly people. Consumption of spinach three to four times a week is considered very helpful for the seniors. Half of iron and most of the calcium in spinach is bound to oxalic acid but the beta-carotene, potassium and vitamin C, counter balance it. Recent research indicates that certain compounds in spinach are cancer fighting flavonoids and spinach is one of the most potent among the high antioxidants in vegetables and fruits.

Spinach is a good source of folate (B9), which functions as a coenzyme, important for making new cells in the body. It is excellent source of heart healthy minerals, as potassium, magnesium and calcium. It is number one source of carotenoids. Frozen spinach retains all vitamins and minerals, keeping it just nutritious as fresh spinach. Its iron content is about 3 g per 100 g is much short of our common belief and is biochemically locked up but spinach is a good source of calcium and potassium, which helps relieve and prevent the symptoms of PMS(post-menopausal syndrome) and menstrual cramps. Calcium and magnesium act as neutral tranquilizers reducing pain, discomfort and irritability (Ahuja *et al.* 2010).

Spinach has the highest level of quercetin - that inhibits cancer promoting cells and influences the heart health. Glutathione, another powerful antioxidant in spinach helps pulling out pollutants and maintains a healthy liver. The folates in spinach are known to help prevent neutral-tube defects in babies. Folates (27% of DA) also dispose off homocysteine - a troublesome amino acid that damages blood vessels. Homocysteine is linked to heart problems, cardiovascular diseases and osteoporosis. Vitamin E is a great antioxidant, that may prevent and dissolve blood clots, may slow the progression of Alzheimer's disease and may significantly strengthen the immune system. Zinc is important in a number of activities,

including wound healing, immune system and vision; selenium works in conjunction with vitamin E, and is a part of several enzymes. Phosphorus, in combination with calcium is necessary for formation of bones and nerve cells (Ahuja *et al.* 2010).

100 g spinach leaves contain moisture (92.1 g), fat (0.7 g), fibre (0.6 g), protein (2.0 g), minerals (1.7 g), carbohydrates (2.9 g), magnesium (84 mg), phosphorus (21 mg), sodium (58.5 mg), copper (0.01 mg), chlorine (54 mg), thiamine (0.03 mg), nicotinic acid (0.5 mg) riboflavin (0.07 mg), calcium (73 mg), oxalic acid (658 mg), iron (10.9 mg), potassium (206 mg), sulphur (30 mg), vitamin A (9300 IU), and vitamin C (28 mg) (Pandita and Lal, 1990).

This leafy green vegetable is easy to grow and easy to use. It is available fresh, frozen or canned. Flat leaf, curly leaf, ruffled leaves varieties are available besides the baby spinach which is mostly used as a salad. Eaten fresh or cooked, it is the queen of the deep green vegetables. It provides so much at such an affordable price and relished by both the poor and the rich alike. Spinach may be cooked like mustard greens or mixed with mustard greens and turnips or boiled and stir-fried with onion and tomatoes. It is a loveable dish when cooked with baby or bullet potatoes and delicious and nutritious when cooked in lentil (dal). Now it is available almost throughout the year. It can rightly be termed as a poor man's richest diet (Ahuja *et al.* 2010).

Botany

Spinach, *Spinacia oleracea* L., is an herbaceous annual plant for leaf production and behaves as a biennial for seed production. It belongs to the family of Amaranthaceae. It produces rosette of leaves from a much shorter stem near the surface of the ground during vegetative phase. Later, stem elongates and forms flower stalks during reproductive phase. Leaves vary in shape, thickness and are smooth or savoyed/wrinkled depending on the cultivar. Flowers are small, greenish, axillary and borne in clusters on both large and small branches. Flowers vary from 6–12 per cluster, but all of them do not develop at the same time. Spinach has leaves with lobed margin.

Spinach is usually dioecious; individual plants produce either all male or all female flowers. But monoecious plants are also rarely located. Spinach plants are classified into 4 types according to the flowering characteristics/sex expression:

1. external male plants- smaller sized, blooming earlier than others. Male plants die after blooming;
2. vegetative male plants- larger sized;
3. female plants- larger sized, remain vegetative for long period. Female plants bloom later in the season and all flower at the same time; and
4. rarely monoecious plants- predominantly staminate, predominately pistillate or purely pistillate early but with some staminate flowers later or almost equally staminate and pistillate flowers throughout the season.

Flowers may be staminate, pistillate or hermaphrodite and remain receptive for a week or longer. The pollen is transferred by wind. The fertilized ovule develops into a one-seeded fruit.

There are two types of seed; prickly and smooth. Prickly seeded varieties have

flatter leaves than those with smooth seeds, which produce more wrinkled foliage. Round/smooth seeded varieties do well in the plains, whereas the prickly seeded varieties do better in the hills.

The seed is multigerm in spinach. A multigerm seed is a seed which occurs as a cluster of seeds fused together and which produces more than one plant when it germinates. The multiple plants must be reduced to one by a process called 'singling'.

Common spinach, *Spinacia oleracea*, was long considered to be in the Chenopodiaceae family, but in 2003, the Chenopodiaceae family was combined with the Amaranthaceae family under the family name 'Amaranthaceae' in the order Caryophyllales. Within the Amaranthaceae family, Amaranthoideae and Chenopodioideae are now subfamilies, for the amaranths and the chenopods, respectively.

Breeding

Spinach is a cross pollinating crop and is pollinated by wind. Polyploidy breeding has been reported in spinach. Heterosis up to 30–40% has been observed in F_1 hybrids and utilized for development of downy mildew and mosaic-resistant hybrids and cultivars. No significant effort has been made to improve upon the old local strains available in various parts of the country. Some of the varieties introduced from the western countries are being grown in certain parts where it is commercially produced. It reported that additive gene effect was observed for leaf size and partial dominance for yield. The inheritance of leaf size depended on a minor gene. Nine gene groups were involved in the inheritance of yield (Nath *et al.* 2002).

Improved cultivars

Spinach varieties come in savoy (wrinkled), semisavoy and flat leafed types, with many cultivars of each. Spinach grows best in the cooler temperatures of spring and fall, although early and late varieties can extend the season into summer and winter.

There are also some *desi* types/local cultivars like Banerjee Giant, Desi Khara Palak, Khara Lucknow and Banarasi (Katvi palak), which are some of the selections made from exotic varieties over the years by the farmers.

Indian Summer (F1): It is an F1 Hybrid, 40–45 days, is a fine, productive, 3-season spinach for spring, summer, and rainy season production. Flattened, semi-savoy leaves are almost like smoothleaf spinach. Very slow to bolt.

Virginia Savoy: This is an improved exotic variety. It is a smooth seeded variety having blistered, large, dark green leaves with round tip. Plants are upright and vigorous in growth. Maturity 30 days. Yield 80 q/ha.

Early Smooth Leaf: This is an improved exotic variety. It is a smooth seeded variety and produces small light green leaves with a pointed apex. Maturity 25–30 days. Yield 60–70 q/ha.

Sporter: It is developed by Bejo Sheetal Seeds and high yielding F1 hybrid. It has broad leaves without fibres and becomes very soft on cooking. It matures in 45 days.

Spinach Early: It is developed by Tropica Green Co.Ltd. Plants are upright with deep green leaves. It is early type and is harvested all the year in tropical high lands. It is resistant to downy mildew races 1 and 3, heat and cold.

There are also some local cultivars like Desi Khara Palak, Khara Lucknow and Banarasi, which are some of the selections made from exotic varieties over the years by the farmers.

Climate and soil

It is strictly a winter season crop and withstands freezing weather better than other crops and does not grow well during hot weather. Spinach is a long day plant. It tends to produce flowers at the cost of leaves under long days, and warmer conditions further hasten the flowering response. Thus planting times are critical for this crop. The yield of spinach was optimum at a soil temperature of 20°C.

The soil requirement of spinach is more or less the same as that of the spinach beet. The soil should be fertile and well drained. The optimum soil pH may be 6–7. Increased yield was reported when grown on sandy soil with humus maintained by the application of mineral fertilizers and farm yard manure. Good drainage is essential. The crop is susceptible to injury by high acidity. Soil temperature influences the crop growth.

Cultural requirements

Sowing time: Usually the sowing in northern plains is done during June-November. In the hills it is done in July-August.

Land preparation and sowing: Land is prepared into a fine tilth. 25 tonnes/ha of FYM should be mixed thoroughly in the soil at the time of field preparation. 33 kg N, 80 kg P and 80 kg K/ha are applied just before sowing.

Sowing is usually done by broadcasting the seeds in the levelled plot. Sowing is also done in rows about 22 cm apart and later on maintaining a spacing of 5–8 cm between plants within the rows. In both the cases, seeds should be placed at a depth of about 4 cm. The seed germinates in about 10 days if proper soil moisture and temperature are available. It requires about 35–45 kg/ha of seeds. The seed rate is relatively high because about 50% of the plants will be male plants with poor growth.

Intercultural operations

The plant has a moderately deep root system but, like other leafy vegetable crops, it should not be allowed to suffer moisture stress. It thus requires fairly frequent irrigation to ensure that the soil does not dry out to less than 50% available water. Soil moisture should never be limiting. In light soils, it is desirable to give irrigation soon after the sowing is complete, but in heavier soils the sowing should be done when enough soil moisture is available. Subsequent irrigations during winter should be given at 6–7 days interval depending on the soil moisture availability. Regular hoeing and weeding should be done.

The crop should be top dressed with 33 kg N/ha after first cutting and with 33

kg N/ha after second cutting. Earthing up is also to be done.

Pest and disease management

Diseases

Leaf spot: Leaf spot is caused by two fungi-*Heterosporium variabile* Cke. Restricted to prickly-seeded cultivar and *Phyllosticta chenodii* Sacc. The former causes dirty white, water-soaked, sharply defined circular spots which appear on the old leaves and the latter causes light yellow specks which develop into spots and result in shriveling and drying up of the leaves. This disease can be controlled by spraying copper oxychloride 50 WP (0.3%).

White rust: This is caused by the fungus *Albugo occidentalis* GW Wilson. The fungus causes white blisters like circular or irregular pustules which appear on the lower-surface of the leaves and opposite each pustule on the upper surface a yellow patch is developed. This can be controlled by spraying copper fungicides and by the other methods including crop rotation and keeping the field free from weeds. Flat or smooth leaf cultivars which are more resistant than the savoy or crinkled leafed cultivars, may be grown.

Downey mildew: This disease is caused by the fungus *Pereenospora effuse* Ces. Infested leaves show light yellow areas on the surface and young plants have pale green, stunted and crinkled leaves. The disease can be controlled by spraying zineb 75 WP (0.2%) thrice at an interval of 15 days.

Root rot and damping off: This disease is caused by the fungus *Pythium* sp. Seedlings are attacked by the fungus and killed. This disease can be controlled by treating seeds before sowing with captan at the rate of 2.5 g/kg of seeds.

Insect pests

Aphids: These insects are small in size and found in large number on the tender portions of the plant. They suck the sap from the plant tissues causing plant to become weak. Aphids can be controlled by spraying malathion 50 EC (0.1%).

Leaf eating caterpillar: The caterpillars of *Laphygma exiqua* feed on leaves and make holes. They are also controlled by spraying malathion 50 EC (0.1%).

Harvesting and yield

It is ready for first trimming in about four weeks after sowing, and the subsequent trimmings may be done at 15 days interval. One crop in the season gives approximately 4–6 cuttings with the total yield of about 50–60 q/ha. In hills where growing season is short the entire plant is cut at the ground level about 5–6 weeks after seeding when plants have 5–6 leaves. The plant should be harvested after they reach the full size but before any of the leaves turn yellow, form seed stalk or die. Whole plants are cut at crown level for the fresh market; for canning, the leaves are cut above the crown.

Before marketing all diseased and yellow leaves should be removed from the produce. Leaves are tied in small bundles for easy handling and marketing.

Under ordinary conditions it is not possible to store it for more than few hours

but under the cold storage conditions it can be stored for 10–14 days at 0°C and 90–95% relative humidity.

Seed Production

The method of seed production is similar to that of spinach beet. Spinach plants produce small flowers. Pollen grains are small in size and light, produced in abundance and carried away by air current. This is a cross-pollinated crop and pollination takes place by wind. Unpollinated pistillate flowers remain receptive for 2–3 weeks. Care has to be taken to remove the male plants which do not produce seeds. However, some of the male plants should be left for pollination purpose.

The isolation distance maintained is about 1600 m in foundation seed production.

For pure seed production rouging is essential. First rouging is done before appearance of flower stalks and plants not true-to-type are removed. Second rouging is done at the time of blooming and early bloomers are removed. Most of the early bolters are males and have no effect on the seed yield.

Spinach produces seed stalks in about 65 days and seeds in about 150 days. Seeds mature slowly and unevenly. Seeds shatter badly from dried plants, hence the seed plants are harvested before they are fully dried. The entire seed bearing plant should be collected, dried and threshed. The seeds are cleaned by winnowing. The average yield of spinach seed is about 740 kg/ha in the plains. However, the late varieties have produced about 100 kg in the hills. The seeds remain viable for 3–4 years under proper storage conditions.

INDIAN SPINACH

Fig. 22. Indian Spinach

Indian spinach is native to tropical Asia, probably originating from India or Indonesia, and is extremely heat tolerant; now widely grown in many tropical regions. It was introduced to tropical West Africa comparatively recently. It is cultivated in tropical Asia (India, Ceylon, the Philippines, Malaysia, Indonesia), the Caribbean, West Africa. In the Philippines, the red-leaved form is grown in preference to cultivars with green leaves. Both forms are cultivated to a limited extent in West Africa. In USA the Americans of Asian origin have started growing this crop. In India it is grown in almost all states. It is now grown in all parts of the tropics and in warm regions of the temperate zone. It is also known as *poi*, Malabar nightshade, Ceylon spinach, Malabar spinach, Baselle, vine spinach, climbing spinach. It is a common leaf vegetable grown in north-east and south India. It is used as a spinach substitute and is not related to the true spinach (*Spinacea oleracea*).

Malabar Spinach has succulent, oval or round leaves, rich in protein vitamins and minerals. It tastes mild and pleasant. Young leaves and stems have an 'earthy' flavor and mucilaginous with slightly slippery texture which one needs to develop an acquired taste to really like this vegetable. The Ceylon spinach can be eaten raw in salads, as a steamed vegetable, or used as thickening agent in stews and soups. The mucilaginous texture is especially useful as a thickener in soups and stews.

The shoots and leaves are relatively high in food value, providing a useful source of vitamins and minerals. The leaves of most forms contain mucilage and are normally cooked with meat or fish. The juice from the fruits is sometimes used as a food colouring.

It is rich in vitamins A and C, as well as iron, calcium and soluble fibre and is believed to possess medicinal properties, where the most well known is that the leaves and stems have a mild laxative effect.

Botany

Malabar spinach is in the Basellaceae family, not the spinach family. There are two main species of Malabar spinach: *Basella alba*, which has green stems and thick fleshy leaves, and *Basella ruba* which has red stems. The diploid chromosome number of *B. alba* is 2n=48 and that of *B. rubra* is 2n= 44. *B. rubra* is very variable. Other botanical forms are *B. cannifolia, B. cordifolia, B. nigra* and *B. saponica.*

It is a fleshy annual or biennial or perennial, twining or much branched. The stems are fleshy, succulent, dark-red-purple or yellowish-green, terete, glabrous and 2–10 m long. Leaves biseriate, petioled, ovate to lanceolate, glabrous on both side. Inflorescence is axillary, solitary, long peduncled; flowers are sessile in the axils of the leaves, regular, bisexual, rose coloured or yellowish white. Fruits are enclosed in fleshy perianth and are globose, dark purple, juicy, shining. The succulent leaves with petiole and tender stems are cooked and eaten as vegetable.

The plant has fleshy stems and leaves and is of trailing habit. It is propagated through seeds or by stem-cuttings. The Ceylon spinach is a perennial herbaceous vine in the tropics. It adopts a creeping growth habit if a support is not provided. Its climbing growth habit becomes apparent whenever a shoot gets hold of one. The leaves of this plant are heart-shaped, green and have a glossy appearance. Older plants produce small, insignificant flowers in clusters and fruits are one-seeded berries. The fruits of the purplish red version ripen to a purplish-black colour and they yield a red dye that is used as ink for seals by court officials in ancient China. This sap is also used as food coloring and acidifying it with lemon juice intensifies the purple colour. The fruits fall off easily from parent plant for self-seeding when mature. As such, the established plants multiply and spread easily.

Breeding

There are not many reports on the attempts to improve this crop. Large sized thick leaf and fleshy stems are the desired objectives in basella breeding. One auto-polyploid with 2n=88, having large and succulent leaves was developed by

colchicines treatment of *Basella alba* seedlings. There is need to initiate systematic breeding programme for collection and maintenance of germplasm and development of high yielding, quality and disease resistant varieties. There is a need to develop lines with negligible amount of oxalates and free nitrates. It is also desired to develop varieties having photoinsensitive and late bolting type that can be grown around the year (Dhua, 1990; Peter, 1998; Mini and Krishnakumary, 2004).

Improved cultivars

There are different types of Indian spinach under cultivation. The most commonly grown one with dark green, round to oval leaves is the green basella (*Basella alba*). The red basella (*B. rubra*) has coloured leaves and stems. The third important type has dark green and cordate shaped leaves.

Climate and soil

Normally basella is a short day plant and it responds to light shading by the production of larger leaves than develop under full exposure to sun. Flowering does not occur in day lengths longer than 13 hours. It is one of the tropical crops which has a C_4 cycle photosynthetic pathway. Basella grows very well in warm moist climate. But it cannot tolerate extremes of temperature. It can be successfully grown under partial shade. Plants are normally tolerant to high levels of rainfall but some cultivars have a degree of drought resistance. It is well adapted to high temperature conditions, low temperatures are liable to reduce the growth rate and lead to the production of relatively small leaves. Cultivation should be avoided in regions affected by frost. The optimum range of temperature is 25–32°C. The crop is usually grown during warm and moist seasons.

The Ceylon spinach is fast growing and can be grown as an edible and ornamental vegetable. It is best grown in a semi-shaded location with moist, fertile, well-drained and loamy soil. A wide range of soil from sandy loam to clayey soil with sufficient organic matter will be the best suited. But it grows well also in muddy soil. Sandy loam soil with a pH of 5.5–6.8 is ideal.

Cultural requirements

Basella is propagated by seeds, as well as stem cuttings. About 12–15 kg of seeds would be required to sow one hectare. One can also grow the Ceylon spinach from seeds but these are not readily available. The easiest way to propagate this plant is by stem cuttings. Stems cuttings of about 20 cm long are used. First trim away the larger leaves to reduce transpiration before planting in beds for rooting. Once rooted, these cuttings can be used for planting.

Basella is grown as a short term crop of 2–4 months without support or as a long term crop grown on trellises. A spacing of 60 cm × 30 cm or 60 cm × 20 cm can be adopted. A basal dressing of 25 tonne/ha of farmyard manure and 60 kg N, 60 kg P, 60 kg K/ha is applied before sowing/transplanting.

Intercultural operations

Since the succulent leaves are to be harvested, frequent irrigations are necessary.

During the rainy season, the frequency can be restricted. Water stagnation should be avoided. When the plants start trailing, they should be trained on the support. It is either staked on bamboo *machans* or trained on trellis. Shallow hoeing in between the plants is done as and when necessary. Use high nitrogen fertilizer to promote growth.

Pest and disease management

This plant is prone to foliar fungal diseases and one can minimize their incidence by improving air circulation or increasing amount of light. The most important diseases infecting this crop are damping off (*Pythium aphanidermatum* and *Cercospora* sp.), leaf spot (*Acrothecium basellae*), *Fusarium moniliform* and a mosaic due to unidentified virus. These diseases can be controlled by treating the seeds. It is recommended that soil can be sterilized before sowing, use light, quick drying, well drained and aerated soil, and early thinning of plants when grown from seeds as preventive measures. Spraying of leaves before harvesting should be avoided. The crop is almost free from insect attack though a minor incidence of the omnivorous "wooly bear" caterpillars of ermine moth is reported.

Harvesting and yield

Because we eat the leaves and the stems, Malabar spinach can be harvested as soon as the main stem is growing well. Snip the leaves and tender stems with scissors as needed. Harvest before the vine flowers for the best flavor. The first cutting starts 45–60 days after planting. A yield of 150–200 q/ha of green matter can be harvested with a crop duration of 120–150 days. Though local strains are available, the research and the station varieties are lacking.

Seed production

Cultural practices for seed production are similar to that for leaf production. It is a self pollinated crop. Proper isolation distance (about 50 m) should be maintained between two cultivars for producing nucleus and foundation seeds.

For seed production planting is to be done through August. Seedlings raised in the seed bed are to be planted in the field. Adequate drainage facilities are to be provided. Sufficient moisture is needed to produce rapid and succulent growth. Inadequate moisture may lead to their wiry stems and small leaves. The frequency of irrigation depends on the soil type.

Seeds are ready for harvest when they are fully matured. Vines start dying and their colour turns brown or yellowish. Seeds are picked manually from the vines and dried on the threshing floor or over canvas in the sun. The seeds are cleaned and separated from plant parts by winnowing and are dried well in the gentle sun light and stored. Seed yield is about 700–800 kg/ha.

AMARANTH

Some species of green amaranth (*Amaranthus* spp.), especially, *Amaranthus gangeticus*, *A. mangostanus*, *A. paniculatus, A. angustifolius,* are supposed to have originated in India or Indo-Chinese region. Other spiecies have originated in various other centres like North America, Central America, Mexico, South

America and Mediterranean region.

There are a number of different types of amaranth. All are grown during the summer and the rainy season. This is the most common leafy vegetable grown during the summer in India. The leaves and tender stems are rich in protein, minerals and vitamins A and C.

Amranth is a common leafy vegetable grown in most parts of India. The fresh, tender leaves and stems give delicious preparation on cooking as in the case of the other fresh leafy vegetables. Cooked similar to spinach or spinach beet, it is a cheap vegetable for the common people and is highly rich in vitamin A and C. Besides having the highest protein contents among leafy vegetables, it also contains carbohydrates, calcium and iron. The vitamin A content in different species varies from 23,000 - 54, 110 IU. The leaves contain 130–173 mg vitamin C, 100–130 mg vitamin B, 4 g protein, 397 mg calcium, 83 mg phosphorus, 25.5 mg iron, 341 mg potassium, 247 mg magnesium and 9200 IU of vitamin A [Pal *et al.* 2004].

Botany

Amranth (*Amaranthus* spp.) belongs to the family Amranthaceae. There are several species of *Amranthus* used for leaves, grains or for both. There is a taxonomic confusion because species are quickly adapted in any environment, differences among various species are small, many specific and common names have been used throughout the world, almost interchangeably and also due to quick intergradation of a species in the region itself where it thrives well when cultivated and appears adapted. In spite of this confusion, some species are sufficiently recognized to merit universal acceptance. The best of the species for grains is *A. hypochandriacus* L. and for edible leaves *A.gangeticus* L., *A. cruentus* L and *A. dubius* Mart ex. Thell. *A. hypochandriacus* was used as a grain in India and Sri Lanka in the 18th century. It became prevalent in the foot hills of the Himalayas during the 19th century, where it became a staple food. It is important now in Nepal, China, Manchuria, Uganda, *etc*. In India, *A. hypochandriacus* and *A. caudatus* (grains) and *A. gangeticus* (leaves) are of major importance. *A. mangostanus* (Syn. *A. tricolor* var *mangostanus*), *A. lividus* and *A. dubius* (a recognized tetraploid) are grown on a limited scale in Orissa and other states. A variety named 'Chhoti Chaulai' had been released by IARI, which is claimed to be of *A. blitum* but does not appear to be amongst the recognized species.

The important species of leafy amaranth, *Amaranthus tricolor* L, occupies a predominant position in India with different morphological forms in colour and shape of leaves. *Amaranthus dubius, A. lividus, A. blitum, A tristis* L., *A. spinosus* L and *A. viridis* are other amaranth species, which are under cultivation.

Amaranthus is an annual herb, erect or trailing, scarce to profuse branched, shallow to deep tap-rooted, stem green to purple, leaf simple, alternate or opposite, colour green to purple. Inflorescence terminal and axillary, branched spikes, flower small, regular, mostly unisexual, monoecious. In general the cultivated species are monoecious.

Breeding

It is a wind cross pollinated crop. Though it is rich in nutritive values, it has

received relatively less attention as regards the work on its maintenance and improvement is concerned. So far collections have been perfunctry and no attempt has been made to determine the range of variation with each species. Most of the species are diploids and rapid progress can be expected from traditional techniques. IARI has recommended the varieties, 'Badi Chaulai' and 'Chhoti Chaulai'. Certain varieties, both grain type as well as the leaf type, have been developed at Coimbatore. While yield, quality and flavour are generally acknowledged for suitability in existing varieties, there is a great need to develop varieties with low oxalic acid content and with insect and disease resistance (Nath *et al.* 2002).

Improved cultivars

Arka Suguna: Developed by IIHR, Bangalore. It is a pureline selection from an exotic collection from Taiwan [IIHR-47]. Leaves are light green, broad and succulent. First harvest in 25–30 days after sowing and 5–6 cuts in 90 days. It is moderately resistant to white rust. Yield 250–300 q/ha. It is recommended for Karnataka.

Arka Arunima: Developed by IIHR, Bangalore. A new mutant which is resistant to white rust and rich in calcium and iron and low in anti nutrient factors like oxalate and nitrates. It is a multicut, purple amaranth variety. Its leaves are broad and dark purple in color. It becomes ready for first cutting in 30 days after sowing. Two subsequent cuttings can be taken at 10–12 days interval with a total yield of 274 q/ha. It grows well in *kharif* and *rabi*-summer seasons.

Arka Samrakhsa: A high yielding variety developed by IIHR, Bangalore. It has high antioxidant activity of 499 mg (AEAC units) and minimum nitrate content of 27.3 mg and 1.34 g of oxalates per 100 g fresh weight of leaves. It is a pulling type amaranth variety with green leaves and stem, yields 109 q/ha in 30–35 days duration.

Arka Varuna: A high yielding variety developed by IIHR, Bangalore. It has high antioxidant activity of 417 mg (AEAC units), nitrate content of 37.6 mg and 1.42 g of oxalates per 100 g fresh weight of leaves. It is a pulling type amaranth variety with green leaves and pink stem, yields 106 q/ha in 30–35 days duration.

Pusa Kirti: Developed by IARI, New Delhi. Leaves green with broad ovate lamina, 6–8 cm long with 4–5 cm wide. Petiole 3–4 cm long. The stem is green and tender. Suitable for growing in spring–summer (March - June) season in the plains. Maturity 30–35 days. Yield 500 q/ha.

Pusa Kiran: Developed by IARI, New Delhi. Leaves are glossy- green with broad ovate lamina. The lamina 7–9 cm long and 6–7 cm wide. The petiole 5.0 – 6.5 cm long. The stem is glossy- green. Suitable for growing in *kharif* (July - October) season in the plains. Maturity 25–30 days. Yield 300 q/ha.

Pusa Lal Chaulai: Developed by IARI, New Delhi. The upper surfaces of the leaves deep-red or magenta, lower surfaces purplish red. The lamina is 8.5 cm long and 6.5 cm wide. The petiole is 4.2 cm long. The stem is deep-red in color. Suitable for sowing in both spring-summer and *kharif* seasons in the plains. Maturity 25–30 days. Yield 500 q/ha in spring –summer and 400 q/ha in *kharif* seasons.

Co-1: Developed by TNAU, Coimbatore. Dark green in color, grows vigorously, high yielder.

Co-2: Developed by TNAU, Coimbatore. Dark green, lanceolate leaves; 20–25days duration; yield 100–110 q/ha.

Co-3: Developed by TNAU, Coimbatore. Green leaves; 20–25 days for harvest; up to 3 months multi cutting, can be taken. Yield 100–120 q/ha.

Co-4: Developed by TNAU, Coimbatore. A dual purpose type for greens and grains. Plants are dwarf, 20–25 days for leaves, 80–90 days for grains. Yield 70–80 q/ha of green and 20–25 q/ha of grain.

Lal Sag: Grown popularly in many states. Belongs to *A. mangostanus,* high yielding Indian variety. Produces seeds early; has small flowers.

Badi Chaulai: Developed by IARI. Green, large leaves; plants tall; 2–3 cuttings can be taken; suitable for summer and *kharif* sowing.

Choti Chaulai: Developed by IARI. Green, plants dwarf. Suitable for spring-summer season. 6–7 cuttings.

AMT 105: Green leaves, stem green with reddish base. Suitable for central zone of Kerala. Yield 13o q/ha.

AMT 237: Green leaves and stem. Suitable for Kerala. Yield 150–160 q/ha of greens.

Climate and soil

Amaranthus is a warm season crop adapted to the condition of hot, humid tropics, but is also suitable for temperate climate during summer. It belongs to a group of plants called C_4 plants, species with efficient photosynthetic abilities that respond best to full sunlight. It has rapid, short growth cycles, high net assimilation rates, low CO_2 compensation point and a low transpiration coefficient. It grows in every type of soil but the best crop is harvested from fertile loamy soils. The proper drainage system in the field is necessary, because this crop is susceptible to waterlogging. The best growing soil pH range is between 5.5–7.5, but some of the strains are successfully grown in soils with the pH up to 10. The soil should be brought to a fine tilth by ploughing 3–4 times and leveling.

Cultural requirements

In the plains of northern India it is normally sown in February-March as take a summer crop. The rainy season crop is sown in June-July or at the break of monsoon. In southern states, where the climate is favorable, it is sown throughout the year.

The main field is prepared by ploughing and harrowing and brought to a fine tilth. During field preparation 25 tonne/ha of farmyard manure is applied.

Amaranth is commonly sown by direct seeding in rows or by direct broadcast. Direct seeding is done in the beds of 2 m × 1.5 m., with a row to row and plant to plant spacing of 30 cm. The seeds are very small and sown shallow at a depth of 1 cm. For direct sowing a seed rate of 2–2.5 kg/ha, is recommended. 50 kg N, 25 kg P, 25 kg K/ha is applied at the time of sowing for pulling types.

For transplanting, the nursery is raised in flat beds having soil, sand, and loam 1:2:1proportion. The seedlings will be ready for transplanting after 3–4 weeks.

Amaranth being a warm season crop, it facilitates year round growing. For transplanted crop the seed rate is 1 kg/ha. For cutting type, 50 kg N, 50 kg P, 50 kg K/ha is applied at the time of sowing. 50 kg N/ha is applied as top dressing after 2–3 cuttings.

Intercultural operations

Moisture in soil is very necessary at the time of sowing both in heavy and light soils. A light irrigation should be given soon after sowing if soil moisture is insufficient. During summer, it is necessary to irrigate the crop at 3–5 days interval. Unlike spinach beet, this crop is erect in growth allowing enough weed growth which may be removed from time to time. Hoeing is easy in the plots with row sowing. 50 kg N/ha is applied as top dressing after 2–3 cuttings.

Pest and disease management

If the white rust and leaf spot diseases are very severe mancozeb(0.2%) has to be sprayed. Leaf eating caterpillar, leaf webber, aphids, scale, stem weevil and blue beetle are the main insects of amaranthus. But if pests like the leaf webber or caterpillars occur, malathion @1.5 ml/l of water is sprayed.

The tender leaves and stems being the economic part to be harvested within 25–30 days (except clipping type where it can be retained upto 90 days) normally no insecticides are recommended. It is advisable to take up the harvest only a week after the insecticide application.

Harvesting and yield

The crop will be ready for the first cutting in about 25–30 days after sowing. The subsequent cuttings of about 4–5 can be taken at an interval of 10–12 days. One hectare of good crop (line sown) gives about 250–300 q green leaves and 200 q of greens by broadcasting.

Seed production

Cultural practices for seed production are similar to that for leaf production. Since it is a wind cross pollinated crop, an isolation distance of about 400 m has been recommended between two varieties. It is a quick growing crop and forms seed in about 10–12 weeks. This is advantageous because after taking a number of leaf cuttings, only few last cuttings can be committed to produce seeds.

Seeds are ready for harvest when they are fully matured and come out when rubbed by hand and the plants start dying. Plants are cut (either whole plant or the seed bearing branches) and dried on canvas or concrete floor. Seeds are extracted by beating with stick when plants dry up. Cleaning is done manually by winnowing and dried in the sun. The seed yield is about 800–1,000 kg/ha.

FENUGREEK

Southeastern Europe and West Asia are considered to be the places of origin of fenugreek. It is found growing wild in North-Western India. Fenugreek is also called as Greek hay, *methi, methi sag, menthai.*

Fenugreek has been used since the bronz age. It is grown throughout the country

Fig. 22a. Fenugreek

for its green leaves, young pods and dry seeds. But it does well in northern India. The seeds are used as condiment in several vegetable, as well as in pickle preparations. These are used in indigenous medicines also like diuretic, tonic carminative, astringent and aphrodisiac. Its leaves are used in making poultice for external and internal swellings. Dry leaves are used for flavoring and seasoning also.

Fresh leaves are cooked as a vegetable and make a delicious dish, especially when cooked with bullet potatoes (small fresh potatoes). Dried leaves also make a spicy cuisine after they are roasted and cooked with potatoes or added to curries. They are also used in Egypt as a flavoring for breads. *Methi* is frequently used in northern India for cooking as a vegetable. Boiled and mashed, makes delicious '*pranthas*'. It is also used in cooking curries.

Fenugreek has the ability to reduce muscular spasm, reduce fever, labour pains, and digestive disorders. It has been used for treatment of non-insulin dependent diabetes, inflammation of stomach and to increase milk flow in nursing mothers. "Coumarin", the flavonoid, in ground seeds (used in curry powders) is believed to inhibit growth of gastric and other cancer cells. The alkaloid, "Trigonelline", has shown the potential in treatment of cervical and liver cancers. The saponin in fenugreek is extracted for use in pharmaceutical products. *Methi* is a well known tonic both in Chinese and Ayurvedic medications. It is used for treatment of bronchial and digestive problems, allergies, gout and arthritis. As in all other herbs, no treatment be given without the prescription of a qualified herbalist. A tea made from leaves and taken regularly imparts a sweet odor to the body. A poultice made from crushed seeds, boiled for 10 minutes and applied to affected areas, improves a poor skin and rids it of spots and pustules (Ahuja *et al.* 2010).

Fenugreek is rich in minerals, protein, vitamin A and C. The nutritive value may differ in different cultivars. 100 g of edible portion of *methi* leaves contain 86.1 g moisture, 0.9 g fat, 4.4 g protein, 1.1 g fibre, 1.5 g minerals, 6 g carbohydrates, 67 mg magnesium, 51 mg phosphorus, 76.1 mg sodium, 0.05 mg thiamine, 360 mg calcium, 13 mg oxalic acid, 17.2 mg iron, 51 mg potassium, 176 mg sulphur, 6450 IU vitamin A, 0.7 mg nicotinic acid, 54 mg vitamin C and 165 mg chlorine (Som and Maity, 1990).

A half hardy annual, with clover like leaves, trefoil, and cream, pale yellow, pea like flowers has a typical spicy fragrance. The compact seed is pale-brown. Light roasting brings out full flavor. Fully developed seed and light roasted leaves are used as flavor enhancing spice in curries. The ground seeds, containing 'coumarin ' are a major ingredient in commercial curry powders. Sprouted seeds make the salad spicy and provide a crunchy texture (Ahuja *et al.* 2010).

Botany

Fenugreek (*Trigonella foenum-graecum* L.) is a self pollinated, small seeded annual legume (family Leguminosae/Fabaceae/Papilionaceae) that is grown as a spice crop. It is an annual erect herb with tri-foliate leaves, papilionaceous flowers and leguminous pods. The plants growing to height of 90 cm, flower in 30–37 days after sowing. Anthesis takes place between 9 AM and 6 PM and plants are typically self-pollinated. Cultivated forms are diploid.. There are two species of the genus which are of economic importance. One is *Trigonella foenum-graecum* L., the common *methi* and the other is *T. corniculata*, *champa* or *Kasuri methi.* These two species differ in their growth habit and yield (Som and Maity, 1990). Cultivated forms are diploid. The diploid chromosome number is 2n=16. Both the types, common *methi* and *Kasuri methi*, differ in several ways.

Common *methi* is quick growing, produces upright shoots, giving 2–3 cuttings, pinkish white bigger flowers borne in axils of leaves, 6–7 cm long straight pods, leaf simple, palmate, seed and flower size bigger than those of *Kasuri* type.

In contrast, *Kasuri methi* is slow growing, remaining in a rosette condition during most of its vegetative growth period, gives 5–6 cuttings, flowers bright orange yellow borne on long stalk, pods 2–3 cm sickle shaped, leaf bi-lobed, flowers and seeds are small.

Kasuri methi or *Champa methi* (*Trigonella corniculata*) is more fragrant and liked much by the *methi* lovers. It is slow growing, with bright orange yellow flowers, and small seeds. The common methi, is fast growing, with pinkish white bigger flowers and seeds. It also gives higher yield than *Kasuri methi,* hence liked by commercial growers. There is also blue fenugreek (*Trigonella caerulea),* a very flavorful variety, is cultivated in Europe. Its leaves are dried and used for flavoring purposes. A Swiss cheese is flavored with this with a unique flavor. It is also used in Rye Bread in Italy and Austria (Ahuja *et al.* 2010).

Breeding

Fenugreek is a self pollinated crop. It is an herbaceous annual which produces seeds freely. Very little efforts have been made in collecting, maintaining or utilization of different genotypes for the improvement of this crop. If the crop is used as leafy vegetable, the maximization of green yield is the major objective for its improvement. Several selections have been released by research institutes/ stations.

Improved cultivars

Pusa Early Bunching: Developed by IARI, New Delhi. Early variety. It is quick growing with upright shoots, good yielder, suitable for 2–3 cuttings. Takes 125 days for seed maturity.

Pusa Kasuri: Developed by IARI, New Delhi. A late flowering variety, rosette type leaves with special fragrance, heavy yielder, and gives 5–6 cuttings. It takes 156 days for seed maturity.

Lam Selection-1: Developed by RARS-APAU, Lam. Plants are of medium height, bushy, more branched. Under irrigated condition it gives a leaf yield of 100–120 q/ha.

Methi No. 47: Leaves are broad, succulent and rich in Vitamin C. Released by Maharashatra state.

Co-1: Developed by TNAU, Coimbatore. A high yielding variety suitable for both greens as well as for seed.

CO-2: Developed by TNAU, Coimbatore. A high yielding variety suitable for both greens as well as for seed.

Hissar Sonali: Developed by HAU, Hisar. It is a variety for green leaves.

Hissar Suvarna: Developed by HAU, Hisar. It is a variety for green leaves.

Hisar Madhavi: Developed by HAU, Hisar. It is a variety for green leaves.

Hissar Mukta: Developed by HAU, Hisar. It is a variety for green leaves.

Climate and soil

Being a cool season crop, fenugreek is fairly tolerant to frost and freezing weather. It can also be grown as a hot weather crop. It is mainly cultivated in moderate or low rainfall areas, while the areas with heavy rainfall are not suitable for its cultivation. Kasuri methi needs a comparatively cooler climate.

The ideal soil for fenugreek is clay loam though it can be grown successfully on all types of soil. It can be grown on various types of soils but well drained loamy soil is best suited. The optimum soil pH should be between 6–7 for its better growth and development.

Cultural requirements

Sowing time: Seeds are sown from September to the middle of November for seed purpose and for leaves it can be sown up to March in the plains of northern India. In the hills it is sown in March-April and October. Kasuri is sown in December.

Land preparation and sowing: The soil should be brought to fine tilth by ploughing three or four times (Nath and Swamy, 2013). Beds of convenient sizes should be prepared at the same time. Seeds are sown from September to the middle of November for seed purpose and for leaves it can be sown up to March in the plains of northern India. In the hills it is sown in March-April and October. *Kasuri methi* is sown in December. The seed rate is 40–45 kg for common *methi* and 30–35 kg for *Kasuri methi* per hectare. Seeds are generally broadcast uniformly. The surface is raked thereafter to cover the seeds well. Line sowing in rows 20–25 cm apart facilitates weeding and intercultural operations during the initial stages of crop growth. Usually, no thinning is required when it is grown for leafy vegetable but it is necessary for a seed crop. A spacing of 5–7.5 cm within the row is generally given for this purpose. The germination is fast and complete within 6–10 days depending upon temperature and the variety. Sufficient soil moisture should be there to get uniform germination.

Fenugreek being a leguminous crop, it doesnot require heavy quantity of nutrients. However, the soil should be fertile enough for getting succulent foliage and early growth. 15 t of FYM, 40 kg of N and 20 kg of P are applied at the time of ploughing and before sowing.

Intercultural operations

In common *methi* one top dressing with 40 kg N/ha can be done if it is kept for

cuttings. 2–3 top dressings of nitrogen, 20 kg each time, should be done preferably after alternate cuttings in K*asuri methi.*

To obtain quick and good growth, frequent irrigations at weekly intervals are necessary depending upon weather conditions. One or two weedings can be done if necessary. Occasional weeds are suppressed by this crop. Broad leaved weeds should be pulled out at the time of first cutting.

Pest and disease management

Frequently, the crop is subjected to the attack by a number of diseases like damping off (*Rhizoctonia solani*), powdery mildew (*Erysiphe polygoni*), rust (*Uromyces anthyllidis*), downey mildew (*Pernospora trigonella*) and leaf spot (*Cercospora traversiana*). But all these diseases are not so serious in fenugreek.

The young crop is attacked by damping off disease. This is caused by a fungus *Rhizoctonia.* It can be controlled by giving a drenching of 0.1% carbendazim in the initial stage of incidence of the disease. Incorporation of one tonne/ha of neern cake at the last ploughing is beneficial to contain the disease. When it is meant for leaf harvest, it would be advisable not to spray any chemical.

Powdery mildew is another serious disease affecting the crop. If it is severe, it can be controlled by dusting 15 kg/ha of sulphur (5% dust).

The crop is not prone to severe damage by any insects. However, leaf eating caterpillars and pod borers are found to occur and these can be controlled by spraying ekalux (0.05%) or malathion (0.2%).

Harvesting and yield

The first cutting is made after 25–30 days of sowing when the plants are 15–20 cm high, leaving 2–3 cm stubs for the production of new stalks. If cuttings are delayed, the leaves become bitter and unfit for consumption. The young plants are nipped at the ground level in common methi after 20 days of sowing. After another 15–20 days the plants are often uprooted, bunched and marketed. Kasuri methi can give 5–6 cuttings at an interval of 15–20 days. The produce is kept in shade and moist conditions. It does not stand storage for more than a few hours. The common methi yields leaves about 70–80 q/ha and kasuri 90–100 q of leaves per hectare.

After 2–3 cuttings plants are left for seeding. Seed yield is high in case of crops grown only for seed.

Seed production

Cultural practices for seed production are similar to that for leaf production. Methi is a self pollinated crop and it produces seeds freely in the plains of India. To produce seeds, an isolation distance of 50 m and 10 m should be maintained for foundation and certified seeds, respectively (Arya, 2003).

Stray plants of wild methi, senji or sweet clover should be rouged out from the seed production plots before flowering and harvesting.

Fenugreek grown for seed should be left in the field until fully mature. The seed crop matures in 155–165 days. Seed pods are resistant to shattering. Seeds are separated as in other legumes. Harvesting for seeds is done when the lower

leaves start shedding and pods become yellowish.Plants are cut with sickles, tied in bundles and allowed to dry for 4–5 days. Threshing should be done on clean cemented floor. Grains are separated by beating with sticks followed by winnowing.

The seed should be dried to below 12% moisture for safe storage. Care must be taken to avoid spoilage in the bin. Fenugreek has been observed to spoil at 15% moisture.

Seed yield is higher if no cuttings are made and left entirely for seed production. 'Pusa Early Bunching' gives a seed yield of 1,200–1,500 kg/ha. Kasuri methi gives a seed yield of 900–1,000 kg/ha. However, seed yield will be reduced if certain cuttings are permitted before leaving the crop for seed production.

MUSTARD GREENS

Primary center of origin of mustard greens is reported to be Central Asia (Northwest India), with secondary centers in Central and Western China, Eastern India, Burma, and through Iran to Near East. It has been cultivated for centuries in many parts of Eurasia. The principle growing countries are Bangladesh, Central Africa, China, India, Japan, Nepal, and Pakistan, as well as southern Russia north of the Caspian Sea. Considered a principle weed in Canada, a common weed in Argentina and Australia, and a weed in Fiji, Mexico, and the United States, Indian mustard is widely distributed as a cultivar and escape in subtropical and temperate climates. Mustard greens is also known as leaf mustard, vegetable mustard, Indian mustard, and brown mustard. The Indian names are *rai,* and *sarson.*

This species is the source of many cultivated forms of Indian and Chinese mustard. It resembles broccoli or collards in appearance, but these cultivated plants are apparently different forms of *Brassica olearacea* (wild cabbage). Indian mustard differs from wild cabbage by the absence of leaves that clasp the central stem. It differs from other *Brassica spp.* (mustards) in the wild by the lack of hairs on the foliage, seedpods, or stems. While some cultivated forms of Indian mustard have leaves that are incredibly hot and spicy, the wild form of this plant has leaves with a mild flavor. They are edible and can be used as a potherb

B. juncea are grown as green vegetables and for the production of mustard oilseed. They are cultivated for the seeds, which are ground and used as a condiment, usually mixed to a paste with vinegar or oil, sometimes with spices or with an admixture of starch to reduce the pungency. Mustards are also grown as salad plants and for greens. The mustard leaves and tender stems form the most popular winter greens in the rural areas of Punjab, Delhi and western Uttar Pradesh. Mustard is rich in protein, minerals and vitamins A and C. The nutritive value may differ from species to species.

In India it is being grown and consumed for over 5,000 years. A mention of this is made in the 'Mahabharat'. India, China, Japan and Nepal are among the leading producers of mustard green. Mustard greens are the leaves of the mustard plant. Young mustard leaves are added to salads. Mustard greens, 'nutrient champs' are an excellent source of vitamin K, vitamin A, vitamin C, folates (B9) and vitamin E. They are very good source of B vitamins, pyridoxine (B6), riboflavin (B2), and a good source of thiamin (B1) and niacin (B3). Besides this chart of

nine important vitamins, mustard greens are rich in seven minerals, manganese, calcium, potassium, copper, magnesium, iron and phosphorous, besides dietary fibre, protein and mono- and poly- unsaturated fatty acids.

Botany

Mustard greens (*Brassica* spp.) belongs to the family Brassicaceae/Crucifereae, the genus *Brassica.* The diploid chromosome number is 2n= 20. A number of species are grown in different parts of the country. Specific varieties/types are available for vegetable purpose. These are:

Brassica campestris var. *dichotoma*- Brown sarson of Punjab.

Brassica campestris var. *campestris*- Lai of Assam.

Brassica campestris var. *sarson*- Yellow sarson of UP, Bihar and Bengal.

Brassica campestris var. *rugosa*- Dried in summer and stored.

Brassica juncia-Banga sarson of Delhi.

Brassica napus- Late type free from attack of aphids and is also grown for tender shoots.

Mustard greens *[Brassica juncea* (L.) Czern.], an adventive or introduced plant is a summer or winter annual about 30–120 cm tall, branching occasionally in the upper half. Initially, there is a rosette of basal leaves, but during warm weather this plant has a tendency to bolt and develops flowering stems. These stems are round and hairless. The alternate leaves are up to 30 cm long and 10 cm across. The typical leaf is pinnatifid, tapering gradually to a stout petiole and becoming broader toward the large terminal lobe. There is a stout central vein along its length. A few of the upper leaves may be unlobed. These leaves are bluish green (usually), glabrous, and glaucous, while their margins are undulate or dentate. The upper stems terminate in narrow racemes of yellow flowers. Each flower is about 1.5 cm across, consisting of 4 yellow petals, 4 yellowish green sepals, a short green pistil with a knobby stigma, and several stamens with yellow anthers. The rounded petals are slightly notched at their tips, and have faint veins running across their length. The pedicel of each flower is about 1 cm long or longer. The blooming period usually occurs from late spring to midsummer, but some plants bloom during the late summer or early fall. Individual plants remain in bloom for about a month. Each flower is replaced by a hairless silique (narrow cylindrical seedpod) that is cylindrical and held more or less erect. The root system consists of a taproot. This plant spreads by reseeding itself.

Improved cultivars

The varieties for leaf purpose are Pusa Sag 1, MR 702 and Pusa Bold.

Pusa Sag-1: This is released by IARI, New Delhi. Leaves large, broad, glabrous, smooth and attractive green, higher in carotene and ascorbic acid. Average yield 700 q/ha. Maturity 35 days.

Climate and soil

This plant typically grows in full sun under mesic (a type of habitat with a moderate or well balanced supply of moisture) to dry conditions. It is not fussy about the characteristics of the soil, and can often be found in clay loam or gravelly

sites. However, fertile soil will produce larger plants. Disease rarely bothers this plant in the wild, although various insects often chomp holes in the foliage. This mustard requires a good sandy loam soil.

Cultural requirements

In India, for pure culture, seeding is at a rate of 4–6 kg/ha; when cultivated with peas or barley, about 3 kg/ha. Mustard seeds sprout reliably in cool soil. The plants thrive in cool weather but quickly go to seed in the heat of summer. As early in the spring as the soil can be worked, seeds should be sown in rows 30–45 cm apart; seeds are sown 1.5 cm deep and 2.5–5.0 cm apart with in the rows. Plants thinned out to maintain a spacing of 15 cm between plants within the rows. The thinning can be used as leafy vegetable. Seeds can be sown again in late summer. In mild win-ter areas, sowing can be again done in fall and winter. About 50 kg N, 100 kg P, and 50 kg K/ha are required. Manure or soil improving crops may also be used. Nitrogen increases seed yield. This crop should not follow other Brassica crops in rotation. For disease control, it is best grown once every 3–4 years.

Intercultural operations

Fertilize lightly when seeds are sown. Water the plants frequently and generously. Control of weeds is essential, and 1–3 intercultivations may be necessary.

Harvesting and yield

For mustard greens, plants are cut off at ground level when they are young and tender. Otherwise, snap off leaves, leaving the growing tip to produce replacements. Leaves 15–30 cm long, which are tender enough to use in salads, are preferred for marketing. Stringy stems are usually trimmed off larger leaves before the leaves are cooked. An yield of about 120–130 q/ha of mustard greens can be obtained.

Seed production

Varieties of mustard within the same species will cross with each other, but there is no crossing between varieties of different species. This means we can safely grow one variety of mustard greens (*B. juncea*), one Black mustard (*B. nigra*) and one Chinese mustard (*B. rapa*) without danger of crossing. Separate the varieties of mustard greens by 800 m for reliable distance isolation.

When grown for seed, off type plants should be rogued before flowering. Growing period is from 40–60 days, depending on variety and weather conditions. Plants generally harvested before fruits are fully ripe to reduce shattering, harvesting usually in early morning. Entire plants are either pulled out by hand or cut a few cm above ground with sickles. Plants are tied into small sheaves and dried in the sun for 4–10 days. Threshing, and winnowing are carried out. In India, seed yields of mustard greens range from 15–20 q/ha. Mustard seeds will last for 4 or more years if properly stored.

CORIANDER

Fig. 23. Coriander

Coriander is a native of the Mediterranean region, where it has been grown since ancient times. It is extensively cultivated in Asia, Europe, North Africa and South America. Coriander is also known as cilantro, Chinese parsley or *dhania* (in Hindi). Cilantro, is the name given to the leaves of the coriander plant, while both the plant and the seed like fruit are traditionally called coriander. Cilantro has a very pungent odor and is widely used. It is actually the leaves (and stems) of the coriander plant.

The green leaves are usually taken as cilantro. The bright green colored leaves have a powerful aroma and flavor. They are frequently used in Indian, Chinese and Mexican dishes and for garnishing with its fresh leaves. Cilantro has soft green leaves with cut edges, an appealing flavor and aroma. The whole plant is aromatic and edible. Lower leaves are round, and upper leaves feathery. White flowers produce light green, round fruits called 'coriander seeds'. Cilantro is frequently used in preparing '*chutney*', mixed with spring onions, mint and other spices. It is commonly used as a dip for fritters, and many other snacks used for the afternoon tea. Coriander seeds are an important ingredient of Indian spices and curry powder, so popular all over the world. The seeds are used in Indian curries and Chinese stir-fry dishes. Crushed seeds are used in *'garam masala'* and in breads in some countries.

Coriander is rich in "coriandrol", which may help protect against liver and breast cancers. About twenty compounds have been identified in coriander, with anti-bacterial actions that help in body odor and bad breath. The leaves help stimulating appetite and relieve irritation. Oil is fungicidal and bactericidal. The oil is also used for flavoring gin, vermouth, tobacco and perfumes. Essential oil is used extensively in the perfume industry and in powders, soaps and toilet waters. Roots are used in Thai cuisines. The seeds are also used in pickles, pickling spices, baked goods, sausages and sauces.

The use of coriander as a spice is very ancient, seeds having been found in Egyptian tombs of the twenty first dynasty and therefore nearly 3000 years old. The Romans have used it for well over 2000 years and the plant was known in England before the Norman conquest; it is naturalized in a few localities in southern England possibly since Roman times. In South-eastern Asia the seeds are used as condiment, as an ingredient of curry powder and chewed with betel nut; they have been employed for flavoring spirits, they are an ingredient in mixed spice and in pot pourri and they have been used in confectionery and even for flavoring bread. The leaves are used as a flavoring imparting a pleasant taste to soups. Bunches of seedlings are usually on sale in village markets in India.

Coriander leaves occupy the next important place to curry leaf in our daily food stuff as a spicy green adjunct. The tender leaves and stems are not only used as spicy green in cooked product but as an important ingredient in salad too along with onion, cucumber, carrot, radish, green chilli and acid lime.

Botany

Coriander (*Coriandrum sativum* Linn.) belongs to the family Apiacea or Umbelliferae and the genus *Coriandrum.* It is an annual growing to 30–45 cm with small white or pinkish flowers in umbels; the leaves are divided into 5–7 pinnae each with many lobes, the lobes being narrower on leaves higher up the stem. There are only two varieties, one with red petioles and the more popular one with green petioles. The fresh unripe seeds have a disagreeable smell which passess as they ripen. It is a quick growing annual which, in the tropics, is ready for pulling for its strong smelling, shining bright green leaves in about 5 weeks from sowing. Seed should be sown in early spring thinly in fertile light soil and the plants are pulled out as soon as large enough to be of use in the kitchen. The diploid chromosome number is 2n= 22.

Improved cultivars

Arka Isha: This is a high yielding, multicut, late flowering (50 days after sowing) coriander variety developed by IIHR, Bangalore. It yields 37 q/ha by pulling at 40 days after sowing and 122 q/ha by cutting (3 cuts). The leaves have 167.05 mg of Vitamin C per 100 g of edible portion. Leaf essential oil yield is 0.083% with good aroma. Keeping quality at room temperature is 3 days and at low temperature it keeps for 3 weeks without loss of aroma when stored in polythene bags (100 PE Gauge).

CO-1: It is a selection from germplasm types maintained at the Department of Spices and Plantation Crops of Horticultural College and Research Institute of Tamil Nadu Agricultural University, Coimbatore. In about 40 days, it can yield 6000–8000 kg of greens. The duration is 110 days.

CO-2: It is a reselection from a type of P2 of Gujarat made at Department of Spices and Plantation Crops of HorticulturaI College and Research Institute of Tamil Nadu Agricultural University, Coimbatore. In about 40 days, it can give the green yield 10,000 kg/ha. Total duration for the harvest of seeds is 90–100 days. This is suitable for dry tracts of Tamil Nadu.

CO-3: It is selection made from IARI type 695. It is resistant to wilt and grain mould.

Sadhana (CS.4): It was developed at APAU, Hyderabad. It is a green cum grain variety. It produces more quantity of leaves. The plants grow to a height of 70 cm. It is resistant to aphids. The crop duration is 100–110 days.

Lam CS 7: It was also developed at APAU. It is used as a leaf and grain purpose variety. It has more number of branches.

Gujarat Coriander 1: This variety is released by Gujarat Agrl.University. It has more branches and hence best suited for leaf purpose.

Gujarat Coriander 2: This variety is released by Gujarat Agrl.University. It has more branches and hence best suited for leaf purpose.

Climate and soil

The optimum temperature for normal growth of this crop is 20°C; when the temperature goes to 35–40°C, the growth is severely affected. Similarly very heavy rains will also hamper the growth of this crop. Well drained loamy soil having a pH of 6–8 would be ideal for growing coriander. To certain extent, it can tolerate alkaline soil also. It thrives in black soil and arid regions.

Cultural requirements

Coriander is sown during June-July and November-December. The winter season crop (November - December sowing) will give better yield. The field is ploughed 3–4 times. At the last ploughing farm yard manure is applied @ 10–15 tonne/ha. Beds of convenient size are formed. Just before sowing a basal application of 10 kg N and 40 kg P/ha should be done.

Coriander seeds should be split into two before sowing. Seeds without splitting will not germinate. For this, the seeds are spread on a rough surface and wearing a strong chappal seeds are rubbed against the rough floor. After splitting, seeds are sown either by broadcast or line sowing at a spacing of 15 cm. A quantity of 10–12 kg of seeds would be required to sow one hectare. The seeds germinate in 8–12 days after sowing.

Intercultural operations

The field is irrigated immediately after sowing. On third day, life saving irrigation is given. Then the field can be irrigated once in 7–10 days. In a line sown crop, the weeding and hoeing would be easier than in a broadcast crop.

Pest and disease management

It is better not to spray any chemical since the greens are going to be consumed mainly as salad. However when the incidence of powdery mildew is severe, wettable sulphur @ 4 g/l of water or carbendazim 1 g/l of water can be sprayed. After harvest of greens is over the crop is left for seed production. Seed production crop can also be sprayed with above chemicals.

Harvesting and yield

About 20–25 days after sowing, the first thinning can be done. Again on 30th day and 40th day two more harvests as green can be taken up. Yield is about 200–250 q/ha. The remaining plants can be allowed to flower and set seeds.

Seed production

Cultural practices for seed production are similar to that for leaf production. Quick to bolt cilantro (or coriander) crosses with other cilantro varieties and can be safely isolated with 800 m of separation between varieties.

The plants, which grow about 60 cm high, are cultivated in rows about 45 cm apart, generally from seeds sown in early spring. Allow seeds to dry completely on plants before harvesting. The seed heads which ripen about midsummer are gathered and dried, then beaten with light rods or flails to separate the seeds. A

seed yield of 4500–5000 kg/ha can be obtained. Cilantro seeds will last for several years when properly stored.

MINT

Fig. 24. Pepper mint

Mint is native to the temperate regions of Europe and Western and Central Asia, East to the Himalaya and Eastern Siberia, and North America. It is a species of mint with a circumboreal distribution (found throughout Eurasia and eastern North America). These aromatic perennial herbs are distributed mostly in the Northern hemisphere. In India, it is largely confined to North India in the States of Uttar Pradesh, Punjab and Haryana. Mint is also known as Japanese mint, field mint, *pudina*, *podina*, wild mint or corn mint.

Pudina leaves have a pleasant, aromatic, sweet flavor with a cool, refreshing, aftertaste.In India Pudina is widely used to make the traditional *dhania – pudina chutney.* It is also used to decorate other food preparations. Pudina leaves are also widely used in teas, beverages, jellies, syrups, candies and ice creams. Pudina is also used for flavouring meat, fish, sauces, soups, stews, vinegar, tea, tobacco and cordials. *Pudina* is also used to flavor alcoholic drinks.

Mint is used for flavouring meat, fish, sauces, soups, stews, vinegar, tea, tobacco and cordials. The mint oil is used for the production of natural menthol, dementhalised oil is for flavouring mouth washes, tooth paste and pharmaceutical preparations.

In medicine, it is used against stomach disorders, rheumatism, in ointments for headaches, in cough drops, inhalations etc. The oil and dried plants are antiseptic, carminative, refrigerant, stimulant and diuretic. Podina is used as a carminative and an expectorant. The plant is highly effective in treating headaches, rhinitis, cough sore throat, colic, prurigo and vomiting. It serves as a good blood cleanser, since it is antiseptic and antibacterial. Pudina plays a significant role in alleviating swollen gums, mouth ulcers and toothaches.

Botany

Mint (*Mentha arvensis* L) belongs to the family Lamiaceae or Labiatae (mint family) and the genus *Mentha.* It is a herbaceous perennial plant growing to 10–60 cm (rarely to 100 cm) tall. The leaves are in opposite pairs, simple, 2–6.5 cm long and 1–2 cm broad, hairy, and with a coarsely serrated margin. The flowers are pale purple (occasionally white or pink), in clusters on the stem, each flower 3–4 mm long. It is propagated by stem cuttings which spreads as runner on the soil surface producing adventitious roots at nodes. Seeds are to be sown in raised beds. Germination is usually fairly quick. Prick out the seedlings and plant them out in the field. *Mentha* species are very prone to hybridization and so the seed

cannot be relied on to breed true. Even without hybridization, seedlings will not be uniform and so the content of medicinal oils *etc* will vary. When growing plants with a particular aroma it is best to propagate them by division. Division can be easily carried out at almost any time of the year, though it is probably best done in the spring or autumn to allow the plant to establish more quickly. Virtually any part of the root is capable of growing into a new plant. Larger divisions can be planted out direct into their permanent positions. However, for maximum increase it is possible to divide the roots up into sections no more than 3 cm long and pot these up in light shade. They will quickly become established and can be planted out in the summer.

Japanese mint (*Mentha arvensis*) is a perennial herb with creeping root stalk and an erect stem, 1–2 quadrangulate branched with short dense hair. Leaves are 2.5 – 5cm long, oblong ovate. Flowers are in auxiliary whorls, none at the top. Plant rises to a height of 0.4–0.8 m. Branching freely, flowers appearing in May-June and again in September-November under cultivation.

Pepper mint (*Mentha piperita*), Bergamot mint (*Mentha citrata*) and Spear mint (*Mentha Spicata*) are also commercially cultivated though on a lesser scale. These species are morphologically variants to that of Japanese mint.

Cultivars

CIMAP-MAS-1, CIMAP-Hybrid-77, Shivalik, EC-41911, Gombi, Himalaya, Kalka, Kosi, Gomati, Damroo, Sambhav, and Saksham, are the high yielding varieties of Japanese mint.

Climate and soil

Temperate to tropical climate is suited for plant growth. Japanese mint can be grown in all tropical and subtropical areas under irrigation. However, it does not tolerate damp winters which cause root rot. Sunny weather with moderate rain is conducive to its luxuriant growth. A sunny position is best for production of essential oils, but it also succeeds in partial shade. Plants are hardy to at least –15°C. Plentiful rainfall during growth and good sunshine during harvest is best suitable during crop growth. Deep soils, loam to sandy loam well drained, well aerated and loose textured soils are suitable. Clay soils are not suitable. A deep soil, rich in humus which can retain moisture, is suitable for mint cultivation. A pH range of 6–7.5 is ideal.

Cultural requirements

Planting Season: In the plains, planting is done during winter months, whereas in temperate climate, planting is done in autumn or spring from December - March or from January- February. Late planting always gives poor yield.

Propagation: Mints are propagated through the creeping stolons, suckers or runners. Stolons are obtained from previous years planting. One hectare of well established mint produces enough planting material for ten hectares. Best time for obtaining stolons is during the months of December-January. About 400–500 kg stolons/ha is required.

Land preparation and planting: Mints require thoroughly ploughed, harrowed

fine soil. All the stubbles of weeds should be removed before the crop is planted. 25 tonnes/ha of FYM is applied at the time of land preparation. Ridges and furrows are prepared at 45- 60 cm apart. 50 kg N + 75 kg P + 37 kg K/ha is given as basal dose in the furrows and covered with soil. The stolons are cut into small pieces (10–12 cm) and planted in shallow furrows of about 7–10 cm deep at a distance of 30 cm within the rows. Stolons are planted half way down on inner side of the ridges. Plant the suckers end to end. Suckers should be set in 5 cm deep and irrigated. Plants should be spaced 30 cm apart in rows.

Flat beds of convenient size can also be formed for planting suckers or cuttings. Cuttings are planted at a spacing of 15 cm × 15 cm and irrigated.

Intercultural operations

In order to keep the top soil loose for better penetration of water, air, sun light and weed free Mentha needs frequent inter culturing weeding and hoeing. Mentha crop requires considerable moisture well distributed throughout the entire growing season. As roots do not penetrate deep in the soil, light and frequent irrigations are recommended. During summer irrigate the crop weekly. 75 kg N/ha is applied as top dressing thrice @ 25 kg/ha each time.

Pest and disease management

Diseases

Rust: The only serious disease is a rust which causes thickened and abnormal shoots. This can be controlled by spraying 0.2% wettable sulphur or dinocap (0.1%).

Powdery mildew: Powdery mildew can be controlled by spraying 0.2% wettable sulphur or dinocap (0.1%).

Stolon rot: Stolon rot can be controlled by spraying of 0.2% mancozeb and 0.1% brassicol.

Insect pests

Leaf roller: Leaf roller can be controlled by spraying systemic insecticide like monocrotophos (0.2%).

Pyralid hairy caterpillar: Hairy caterpillar can be controlled by application of 5% dipterex.

Termites: Termites can be controlled by soil application of 3% heptafan @ 50 kg/hectare before planting.

Nematodes: Nematodes can be effectively controlled by soil application of fenamiphos @ 11.2 kg/hectare.

Harvesting and yield

As a fresh herb, leaves are stripped whenever required. The first harvest can be taken up 45–60 days after planting. Subsequent harvests can be done once a month throughout the year. After each harvest urea is applied @10–15 g along with 5 kg of farmyard manure per square metre area and irrigated. Yield varies from 100–150 q/ha.

●

CHAPTER 20

Under-utilized/Minor leafy vegetables

A number of other vegetables which are grown on a limited-scale during the winter and used as greens are chard, water spinach, kale, New Zealand spinach, buck wheat, wild spinach, quinova, sorrel, orach, sweet leaf, agathi, seakale, pisonia, rhubarb, pacific water leaf, portulaca, water amaranth, parsley, black nightshade, waterleaf, kenaf and Indian pennywort.

CHARD

Chard [*Beta vulgaris* L. ssp. *cicla*(L.) Alef.] belongs family Amaranthaceae It is closely related to *palak*. The leaves are bigger and the leaf stalk and veins are white. It is not commonly grown in India. It needs cool climatic conditions for proper development. Swiss chard is a popular substitute for true spinach (*Spinacia oleracea* L.); and it furnishes a considerably higher yield. It is grown with less trouble and has a similar flavour to spinach. It is a biennial but is grown as an annual. It is commonly, but incorrectly, called spinach, and is a very close relative to beet root (*Anon.,* 2011b).

Chard is also known by other common names such as Swiss chard, silver beet, perpetual spinach, spinach beet, crab beet, bright lights (due to the bright and vivid spring colours when they are cooked or provided as a medley of vegetables), seakale beet, and manrigold. It is cultivated descendants of the sea beet, *Beta vulgaris* subsp. *maritima*. Although the leaves are eaten, it is in the same group and sub-family as beet root (garden beet), which is usually grown primarily for its edible roots. Chard and the other beets are chenopods, a group which is either its own family Chenopodiaceae or a sub-family within the Amaranthaceae.

The chard is very popular among Mediterranean cooks. The first variety was traced back to Sicily. Chard can be harvested while the leaves are young and tender, or after maturity, when they are larger and have slightly tougher stems. Raw chard is extremely perishable. Chard has shiny green ribbed leaves, with stems that range from white to yellow to red, depending on the cultivar. It has a slightly bitter taste. Fresh young chard can be used raw in salads. Mature chard leaves and stalks are typically cooked or sauteed; their bitterness fades with cooking, leaving a refined flavour which is more delicate when compared with of cooked spinach. The leaves are prepared like spinach and the leaf stalks sometimes like asparagus or celery. Swiss chard is a good source of magnesium, iron and potassium (K), as well as vitamin A and ascorbic acid (vitamin C), but it is low in

calories (21 cal per 100 g) and fat. Half the ascorbic acid is lost in cooking, and some of the minerals and vitamins are released to the cooking water, so the volume of water could be reduced.

Cultivars of chard include green forms, such as 'Lucullus' and 'Fordhook Giant', as well as red-ribbed forms such as 'Ruby Chard' and 'Rhubarb Chard'. The red-ribbed forms are very attractive in the garden, but as a rough general rule, the older green forms will tend to out-produce the colorful hybrids. All parts of the chard plant contain oxalic acid. Swiss chard is high in vitamins A, K and C, with a 175 g serving containing 214%, 716%, and 53%, respectively, of the recommended daily value. It is also rich in minerals, dietary fibre and protein.

In warmer, frost-free areas Swiss chard is generally sown from February to August. In temperate regions it is sown in August/September, but in sub-tropical region, it is sown upto February. In most other parts Swiss chard is sown from January to April, or from July to September. This is an important vegetable in northern India and subtropical regions of South America. These are similar to those of the garden beet except that wider spacing is normally given to the plants, 60–75 cm between the rows, 20–30 cm between the plants. The outer leaves are harvested singly as they mature, after about 50–60 days from sowing. Yields of Chard can be obtained up to 100 q/ha. The seed is produced only in the hills.

WATER SPINACH

Water spinach (*Ipomoea aquatica*) is of East Indian origin and a member of the Convolvulaceae (morning glory) family. It has long, jointed and hollow stems, which allow the vines to float on water or creep across muddy ground. Adventitious roots are formed at nodes which are in contact with water or moist soil. They exude a milky juice, and are white or green, depending on variety. Water spinach is not related with common spinach, but is closely related to sweet potato (*Ipomoea batatas*). Water spinach is also known as water convolvulus, kang cong, kang kong and swamp cabbage.

Water spinach is an herbaceous aquatic or semi-aquatic perennial plant of the tropics or sub-tropics. Leaves are flat, and vary in shape depending on variety, from heart-shaped to long, narrow and arrow-shaped. Narrow leaves are 1–2.5 cm wide and 20–30 cm long. Broad leaves are up to 5 cm wide and 15–25 cm long. The large, attractive flowers have the typical open, trumpet shape of convolvulus or bindweed flowers. They are usually white, sometimes with a pinkish centre. Wild forms may have purple or mauve flowers. The leaves have a very pleasant, mild, sweet flavour and a slightly slippery texture, which contrast when cooked with the crispness of the stems. The Chinese consider the white-stemmed forms better flavoured and tenderer than the green. Like many other leafy vegetables, water spinach's leaves are very nutritious, being rich in vitamins and minerals. They are also a mild laxative.

There are two major cultivars of water spinach, viz., (*i*) Ching Quat (known as "green stem") – this has a narrow, pointed leaves and white flowers and is adapted for moist soils. This can be grown in beds, provided there is always plenty of moisture. (*ii*) Pak Quat (known as "white stem") – this has broad, arrow-shaped

leaves and pink flowers. It is adapted to aquatic conditions and also called 'Water Ipomea'.

Practically all parts of the young plant are edible, although the shoot tips and younger leaves are preferred. Water spinach is consumed differently in Western and Chinese cuisines. Water spinach deteriorates rapidly once picked, so must always be used very fresh. The leaves can be used whole, or cut into smaller pieces. Like ordinary spinach, the stems require slightly longer cooking than the leaves. Coarse stems and leaves are often used for animal fodder.

Water spinach is not adapted to climates with mean temperatures below 10 °C and the optimal temperature is around 20°–30°C. It is grown year-round in the tropics. Flowering occurs under short-day conditions and commences from mid-summer onwards. Water spinach is perennial in warm climates, but an annual under cooler growing conditions. It tolerates very high rainfall, but not frost. Water spinach can be grown outside in summer. In cool areas, it can be grown in unheated greenhouses in summer, but will require heated greenhouses for a spring crop. It prefers full sun but where summer temperatures are very high, it is sometimes grown as a ground cover beneath climbing plants. Water spinach should be sheltered from strong winds.

Water spinach requires fertile soils rich in organic matter. Overwatering can leached out readily available nutrients and will affect yield. Therefore slow releasing fertilizers are recommended to avoid the loss of nutrients. The most suitable soil pH ranges from 5.5 to 7.0.

In moist soil culture, the crop is grown on raised beds 60–100 cm wide. Seeds are sown directly or nursery-grown seedlings are transplanted into the beds. Seed should be no more than 2 years old and can be soaked for 24 hours before sowing to encourage germination. Soil temperature requirement for germination is 20°C. When rainfall is low, frequent heavy irrigations are necessary for high quality shoots.

To produce strong seedlings, seed should be sown 5–10 mm deep in trays with potting mix deep enough to allow the plants to develop a good root system. Transplanting should take place when plants are 10–15 cm high, with four true leaves. Highest yields are obtained by spacing plants at 15 × 15 cm. They can also be grown in rows about 30 cm apart with plants at 20 cm spacing within rows.

Water spinach can also be raised from stem cuttings, 30–40 cm long, taken from the young growth just below a node, and planted about 15 cm deep. To ensure earliness, growers in China sometimes lift roots at the end of the season, store them carefully in winter, and plant shoots from them in spring.

For aquatic culture, cuttings from the broadleaved cultivars are transplanted into puddled soil, similar to the planting of rice in paddies. The cuttings are about 30 cm long with seven to eight nodes, and are planted 15–20 cm deep and spaced 30–40 cm apart.

For aquatic culture after planting the land is flooded to 3–5 cm in depth and the water is kept flowing continuously. In moist soil culture, irrigation should take place every 1–2 days for high quality shoots if rainfall is low.

Before planting, the crop must be given sufficient nutrients to produce quality

spinach. After the plants are established, nitrogen in the ammonium form should be applied at the rate of 40–50 kg/ha, then the water level is raised to 15–20 cm depth. Plants respond well to nitrogen, but over-feeding must be avoided because high nitrate concentrations in the leaves and stems can give undesirable result.

The main fungal diseases, which affect water spinach, are stem rot (*Fusarium oxysporum*) and black rot (*Ceratocystis fimbriata*). For prevention of fungal diseases strategies such as use of clean land and rotate crops every third or fourth year, carefully select stems for propagation that are disease free. Internal cork, chlorotic leaf spot, yellow dwarf and russet crack are viral diseases which .can also affect water spinach. The most important insect pests are leaf beetle, aphids, and wire worm.

Water spinach should be harvested before it flowers. In the semi aquatic type, the crop is ready for harvest 50–60 days after sowing, when entire plants are pulled, washed and bundled. More than one harvest can be taken if shoots are cut above ground level, allowing secondary shoots to grow from nodes below the cut.

In the aquatic type, the first harvest can be made after about a month of good growth. The frequency of harvesting will depend on the growth rate of the crop. The upper part of the main shoot, about 30 cm long, is cut about 5 cm above water level. Bundles of 8–10 shoots are marketed. Removal of the main shoot stimulates horizontal shoot growth. These new shoots can be harvested in 4–6 weeks, depending on plant vigour and temperature. About 400 q/ha can be harvested from three or more cuttings in a year.

Rapid and careful post harvest handling is required to minimise damage to the fragile crop, especially due to wilting caused by moisture loss. To prevent this, the plants should be harvested during the coolest part of the day. After bunching, a fine spray of cold water should be applied, and the leaves kept in a cool place away from the wind.

KALE

Kale or borecole or *karam saag* is a form of cabbage (*Brassica oleracea* L.var. *acephala*), belonging to the family Brassicaceae/Cruciferae, the genus *Brassica,* the species *oleracea* and the variety *acephala.* The original wild cabbage (*Brassica oleracea* ssp. *oleracea*) from which kale, was developed, still grows along the coasts of North Africa and Europe. Kale probably was the first brassicas to be cultivated, and they are quite similar to the wild cabbage that still persists. It can be green or purple, in which the central leaves do not form a head. It is considered to be closer to wild cabbage than most domesticated forms. The species *Brassica oleracea* contains a wide array of vegetables including broccoli, cauliflower, collard greens, and brussels sprouts.

All members of the genus *Brassica* contain very high levels of antioxidant and anticancer compounds. Some authorities say that kale has the highest concentrations of all. Some of these compounds enhance antioxidant and detoxification effects in the body. Others inhibit tumor growth; some block cancer causing compounds, and some prevent the formation of carcinogens. It is suggested

to increase the intake of kale, cabbage, and other brassicas. It has also been reported that compounds in brassicas can protect the eyes against macular degeneration. So, eat those greens. Kale is very high in beta carotene, vitamin K, vitamin C, lutein, zeaxanthin, and reasonably rich in iron and calcium. Kale is also a good source of carotenoids.

It is very popular in Kashmir and is also grown to some extent in Asom. The young shoots and leaves are used as greens.

Kale is biennial, usually grown as annual for their edible leaves which do not form dense heads like cabbage. Kale leaves are fringed or wavy-edged. There are many cultivars of kale. Some were selected more for ornamental use than food. The kale varieties for raw eating in salads is 'Vates Dwarf Blue Curled', 'Tuscan' and 'Lacinato' are primitive kales with very dark green, narrow, upright, savoyed (crimped) leaves that are as ornamental as they are tasty.

Kales grow best in full sunlight. Regular watering is best for good growth. Kale can take freezing temperatures down to at least –7° C. It only makes them sweeter. It is heat that puts the damper on this cool weather vegetable. But kale, like cabbage, broccoli, and cauliflower, peters out when temperatures start getting above 27° C on a regular basis.

Kale is the easiest of the brassicas to grow. It is grown from seeds which germinate in 3–7 days. Planting is done in September or October and harvest leaves as needed from November through April. We can begin harvesting leaves 30 days after planting. Harvest outer leaves from kale plants for cooking as we need them. Use the young, frilly leaves of kale fresh in salads.

NEW ZEALAND SPINACH

New Zealand spinach (*Tetragonia expansa* Murr. Syn. *T. tetragonioides*) belongs to the carpet weed family Aizoaceae, the genus *Tetragonia,* and the species *expansa.* It occurs in India, and New Zealand. A large genus of herbs or sub-shrubs occurring in the southern hemisphere and Japan. It is now cultivated in most parts of the tropics and temperate regions but still is a minor crop.

It is a drought-resistant annual trailing vine with triangular shaped, thick, green and succulent leaves, spreading to a distance of 1–1.5 m. Leaves borne on thick petioles. Flowers are of green colour outside and yellowish green or pale green inside. The herb is drought resistant, but cannot withstand heavy frost. The plant is slow growing and yields less leafy matter than spinach.

Some species are cultivated for their pleasantly flavoured edible leaves which are substituted for spinach. The leaves resemble spinach but are smaller. The plants are much branched and spreading. It thrives during the hot weather and replaces spinach when the latter is not available.

The crop is propagated by seeds, which germinate over a long period of time ranging from 2 weeks to 3 months. Soaking the seeds in water for 24 hours prior to sowing reduces the germination time. It is usually grown on beds 1 m wide and spaced 50–100 cm between plants. A balanced fertilization programme is recommended with adequate soil moisture for rapid growth required for good quality and high yields. From seedling emergence to first harvest requires about 40–50 days. Tender shoots of 15–20 cm long are cut and used like common spinach.

After the first cutting, the plants produce many upright branches which are cut in subsequent harvests.

BUCK WHEAT

Buck wheat (*Fagopyrum tataricum* Gartn.) belongs to the family Polygonaceae, the genus *Fagopyrum* and the species *tataricum* It is also known as Tartary buck wheat, duck wheat, India buck wheat, India wheat, green buck wheat, or bitter buck wheat. It is a domesticated food plant in the genus *Fagopyrum* in the family Polygonaceae. Tartar buck wheat was domesticated in east Asia. While it is unfamiliar to the West, it is still eaten in the Himalayan region today. With its congener common buckwheat, it is often counted as a cereal, but unlike the true cereals the buck wheats are not members of the grass family. Thus they are not related to true wheat. Tartary buck wheat is bitterer, but contains more rutin than common buck wheat. It also contains quercitrin.

It is very commonly grown in the hills of Himachal Pradesh. The tender tops are picked periodically for use as greens. In the hills it is sown with the break of the monsoon. It is an annual growing to 0.8 m. It is in flower from July-September. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by Bees, flies. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils, requires well-drained soil and can grow in nutritionally poor soil. The plant prefers acid, neutral and basic (alkaline) soils and can grow in very acid soils. It cannot grow in the shade. It requires dry or moist soil.

Leaves are used as raw or cooked. Acceptable raw when added in small quantities to mixed chopped salads, otherwise the leaves are much better cooked. They are rich in rutin. Seeds are also cooked as a cereal. The seeds can also be sprouted and used in salads, or ground into a powder and used as a cereal. An edible oil is obtained from the seeds.

WILD SPINACH

Wild spinach (*Chenopodium album* L.) belongs to the family Amaranthaceae and the genus *Chenopodium.* It is also known as *bathua*, pigweed, lambs quarter, fat hen (used for fattening poultry), goosefoot. Chenopodiaceae are a family of flowering plants, also called the Goosefoot family. They are now included under the family Amaranthaceae. The vast majority of Chenopods are weeds, and many are salt and drought tolerant. It is one of the most common winter weeds.

Its leaves are sometimes used as greens. It tastes better than spinach, both for flavour and nutrition. It is one of the best sources of beta carotene, calcium, potassium, and iron in the world: also a great source of trace minerals, B-complex vitamins, vitamin C and fibre.

The plants are clumping in nature with 2.0–3.0 m long and they are annuals. The leaf is diamond shaped, wavy teeth margins, pale green whitish underneath, alternate branching. It is growing wild and is also cultivated on a small scale in many places.

Usually it is cooked like spinach or mixed with spinach. It helps relieve gas. It has been used as a medicinal plant for its blood purifying properties and some

laxative effects. Now it is not cultivated as a crop, but only occasionally planted by small garden owners. It is a common weed growing in our fields. It is believed that it has medicinal effects for stomach disorders.

This is another nutritious leafy vegetable belonging to the family of *palak* and beetroot. The leaves have waxy margin which are dull green in colour with a pale pink centre. Leaf lamina possesses a waxy coating. So the contact with water does not wet the leaf surface.

It is propagated through seeds. Seeds are slightly smaller than the mustard seeds. Seeds can be directly sown in the field or seedlings can be raised in nursery. Thirty days old seedlings are transplanted in the mainfield at a spacing of 30 cm × 15 cm. After about 35–40 days, either seedlings can be uprooted or clipped near ground level and used as greens

QUINOA

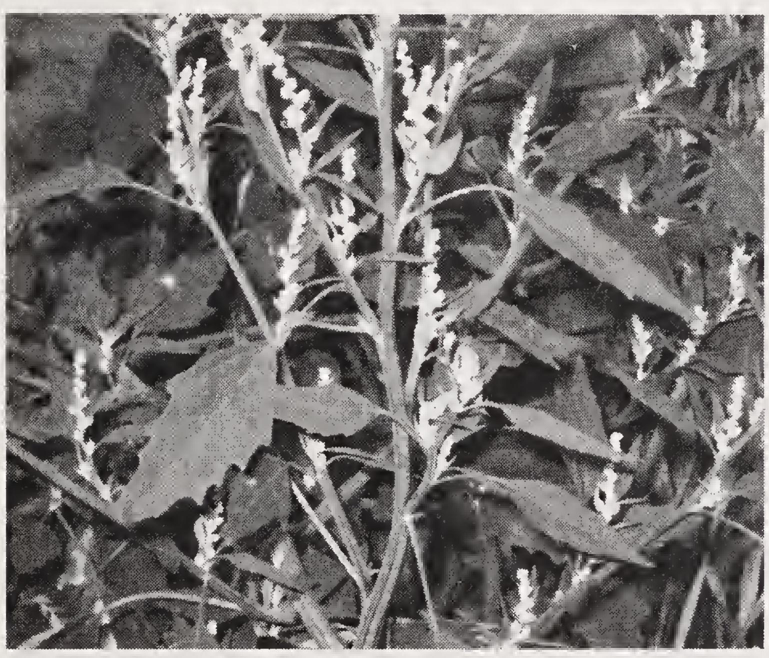

Fig. 24b. Quinoa

Quinoa (*Chenopodium quinoa*) or pigweed, is native to South America. Its green leaves are used like spinach and cooked like spinach. Quinoa leaves are also eaten as a leaf vegetable, much like amaranth, but the commercial availability of quinoa greens is limited. These leaves have a mild plant toxins and so consumption in large quantities is not advisable.

It is important as a cereal grain and now used as a staple food in many places. It flourishes at higher altitudes. A large number of varieties are grown in the Andes. Red variety is grown in Bolivia and black quinoa is grown in Colrado (USA). Red and black varieties are not very common. A mixture of these coloured varieties cooked together look very attractive.

Quinoa grain can be used like rice, barley, millet or couscous, as a side dish; in salads, soups and casseroles; as a hot cereal. Before cooking, it needs rinsing to remove any traces of a bitter coating, called saponin. Quinoa is higher in protein than most grains. It is also one of the rare vegetable sources of complete protein. It is a good source of manganese, magnesium, iron, copper and dietary fibre; half a cup of it contains almost two servings of whole grain. This whole grain product with dietary fibre helps lower the risk of high blood pressure and heart attack. The magnesium in it relaxes the blood vessels. Quinoa flakes, quinoa flour and quinoa pasta are also available. These products are gluten free. Taste of quinoa varies considerably from slightly sweetish to subtly herbal taste. Its cultivation and use need encouragement for its high nutritional value, in Indian subcontinent. It may be the cheapest source of vegetable protein.

Quinoa (*Chenopodium quinoa*) belongs to the family Amaranthaceae and the genus *Chenopodium.* The vast majority of Chenopods are weeds, and many are

salt and drought tolerant. It is a grain like crop grown primarily for its edible seeds. It is a pseudocereal rather than a true cereal, or grain, as it is not a member of the true grass family. As a chenopod, quinoa is closely related to species such as beets, spinach and tumble weeds. Quinoa is a dicotyledonous, annual plant usually about 1–2 m high. It has broad, generally pubescent, powdery, smooth (rarely) to lobed leaves normally arranged alternately. The woody central stem is either branched or unbranched depending on the variety and may be green, red or purple. The panicles arise either from the top of the plant or from axils on the stem. The panicles have a central axis from which a secondary axis emerges either with flowers (amaranthiform), or bearing a tertiary axis carrying the flowers (glomeruliform). The green hypogynous flowers have a simple perianth and are generally bisexual and self fertilizing. The fruits are about 2 mm in diameter and of various colours — from white to red or black depending on the cultivar.

SORREL

Sorrel (*Rumex vesicarius* L.) belongs to the family Polygonaceae, the genus *Rumex,* and the species *vesicarius*. The other common names are, bladder dock, blister sorrel, country sorrel, rosy dock. In Hindi it is known as *chooka, khatta palak*. In Ayurveda it is called as *chukra, chuko, chakravarti*. It is native to South-west Asia and North Africa; cultivated all over India, especially in Tripura, West Bengal and Bihar. Cultivated for its edible leaves in Indonesia and occasionally sold in local markets. Leaves are consumed raw or cooked. An acid flavour, they are used like sorrel as a flavouring in salads or as a spinach.

The plant is cooling, tonic, analgesic, laxative and stomachic; useful in heart troubles, tumours, constipation, hiccup, flatulence, asthma, bronchitis and piles. Leaf juice is astringent, cooling, aperient and a strong diuretic; relieves toothache, checks nausea and promotes appetite.

Leaves are rich in ascorbic, citric and tartaric acids. Roots contain rumicin and lapathin, identical with chrysophanic acid. The aerial parts of this and other species of *Rumex* also contain anthraquinone derivatives and flavonoids like emodin, aloe-emodin, chrysophanol, chrysophanic acid, physcion; isovitexin, iso-orientin, quercetin, kaempferol and luteolin glucosides; chromone and flavone derivatives, tannins, mucilage, calcium oxalate and starch.

Plants can contain quite high levels of oxalic acid, which is what gives the leaves an acid-lemon flavour. Perfectly alright in small quantities, the leaves should not be eaten in large amounts since the oxalic acid can lock-up other nutrients in the food, especially calcium, thus causing mineral deficiencies. The oxalic acid content will be reduced if the plant is cooked. People with a tendency to rheumatism, arthritis, gout, kidney stones or hyperacidity should take especial caution if including this plant in their diet since it can aggravate their condition.

Rumex vesicarius is an annual, 10–30 cm high, branching from the base. Branches are somewhat succulent, glaucous and fragile. Stalked leaves are triangular-arrow-shaped, entire. Flower racemes are simple or branched. Flower stalks are solitary, bearing twin flowers. It is in flower in May. The flowers are

hermaphrodite (have both male and female organs) and are pollinated by wind. Leaves of fruit-bearing primary flower nearly circular, 1.2–1.8 cm long and broad, without a marginal nerve, entire, net-veined. Fruit is somewhat smaller, folded together with the primary one and hidden by it. Nut of primary flower is 3.4–4.7 mm long, greyish-brown, that of secondary flower 2.8–4 mm, darker brown. Flowering takes place during March-May. It is grown for its sour leaves. When the plants flower, they look very attractive and are often used as an ornamental plant.

ORACH

Chakwat (*Atriplex hortensis* L.) commonly known as orach or mountain spinach, belongs to the family Chenopodiaceae, the genus *Atriplex*, and the species *hortensis*. Its origin is reported to be northeren India. It was first used medicinally by the early Greeks and later as a food plant. The crop was introduced from the Mediterranean region to France, then to England and eventually to the United States where it is now popular. It is grown on a small scale in Maharashtra and Karnataka during winter season and in Kashmir during warm season. The plant is characterized in the young stage by tender stems and soft and attractive green leaves. The young plants are either pulled by the roots or the tops are cut periodically.

The variety Chakwat No. 11 has been released by the Department of Agriculture, Maharashtra. *Chakwat* is propagated through seeds and are sown in 60–90 cm distanced rows at 45–60 cm apart. About 5 kg of *chakwat* seeds are enough to sow one hectare. The depth of sowing should be less than 2.5 cm.

It has a somewhat strong flavour than spinach. The leaves become suitable for harvest 4–5 weeks after sowing. In the later stages, the tender leaves can be picked from the branches of the mature plants. It is grown on a smaller scale in Kashmir during summer. A full grown plant gives around 900 g of edible leaves, and from one hectare 70 q of vegetable can be harvested.

SWEET LEAF

Fig. 24c. Sweet leaf

Sweet leaf (*Sauropus androgynous* L.) belongs to the family Euphorbiaceae and the genus Sauropus. Although it is sometimes referred to as katuk, star gooseberry, sabah vegetable, *Sauropus androgynous* is better known via its Malay name 'cekur manis'. It is a perennial shrub that is grown in tropical regions where it thrive and grows rapidly in the hot humid lowland weather conditions. If allowed to grow, the plant can attain a height of about 2.5 m high. It bears pinnate dark green, oval leaves, which sometimes have silvery speckled markings

on the upperside.

For use as a leafy vegetable, tender young leaves are harvested from the top 15 cm of stem tips. They have a pleasant, slightly nutty taste, which is sometimes likened to be similar to that of fresh garden peas and a texture that resembles asparagus. They can be eaten raw in salads, steamed or stir-fried with egg and dried achovies. Notably, the leaves of Sauropus androgynous are well known for their ability to retain their dark green colour and firm texture on cooking. Some individuals prefer to have the leaves removed from their thin wiry petioles before cooking them so as to avoid the trouble of having to remove the leaves from their petioles at the dinner table.

It has a high level of provitamin A, vitamins B, C and K, protein and minerals in freshly picked leaves. Nutrient content of the leaves is usually higher in more mature leaves. Although *Sauropus androgynus* is a nutritious vegetable, one should be cautioned from consuming excessive amounts, especially in the raw form as several cases of poisoning have been reported previously in Taiwan which resulted in progressive obstructive lung disease.

AGATHI

Fig. 24d. Agathi

Agathi (*Sesbania grandiflora* L.; Syn. *Agathi grandiflor; Robinia grandiflora*) belongs to the family Papilionaceae/Fabaceae and the genus *Sesbania.* It is also called as humming bird tree, agati, corkwood tree, sesbãnia, scarlet wisteria tree, swamp pea, vegetable humming bird, West Indian pea. In Hindi it is known as *mar.* It originated from Indonesia and India. This is a small soft wooded tropical tree of 10 m height, with large pink or white flowers. These flowers are hermaphroditic and pollinated by birds. The leaves are 23–25 cm long with oblong leaflets. Agathi has large pods, 2–4 cm long. The seeds in the pods are red brown.

The young tender pods are edible and used as a vegetable in Southeast Asia (Indonesia and India) and Suriname. The flowers and leaves are also consumed as vegetable. The dried leaves are used as a tea which is considered to have antibiotic, antitumor and contraceptive properties.

SEAKALE

Seakale, *Crambe maritima* (common name seakale) is a species of halophytic flowering plant in the genus *Crambe* of the family Brassicaceae/Cruciferae, that grows wild along the coasts of Europe, from the North Atlantic to the Black Sea. Growing to 75 cm by 60 cm, it is a mound-forming, spreading perennial. It has large fleshy glaucous collard-like leaves and abundant white flowers. The seeds come one each in globular pods. The plant is cultivated both as an ornamental

plant and as a vegetable, related to the cabbage. It is in flower from June to August. The flowers are hermaphrodite (have both male and female organs) and are pollinated by bees, flies, self. The plant is self-fertile. It is noted for attracting wildlife.

It is a hardy perennial grown for its young leaves and shoots. This is also not commonly grown in India. Sea kale that grows wild along the coasts of Europe, from the North Atlantic to the Black Sea. It has large fleshy glaucous collard-like leaves and abundant white flowers. The seeds come one each in globular pods. The plant is sometimes grown as an ornamental but its most common use is as a blanched vegetable. Sea kale is more commonly used in Europe and only rarely grown in India. Sea kale should not be confused with sea kale beet/Swiss chard.

Young leaves – raw or cooked like spinach. They have a pleasant almost nutty flavour and go well in a mixed salad. They also make a very pleasant cooked vegetable. Older leaves develop bitterness and are not so pleasant. Young shoots – raw or cooked. Available in the spring, they have a delicate nutty flavour with a crisp texture. The shoots are usually blanched and can be cooked like asparagus. When properly cooked they retain their crispness and have a very agreeable flavour, somewhat like hazelnuts but with a slight bitterness. Root – cooked. Rich in starch and sugars. Young flower buds – raw or cooked. The flowering shoots are harvested when about 10–15 cm long and before the flowers have opened. Used like sprouting broccoli, they are quite nice raw and delicious when lightly steamed.

This species is hardy to about –20°C, it grows best in a cool maritime climate. Seakale is sometimes cultivated for its edible young shoots in the spring which are blanched by excluding light in order to make them less bitter. Two or three crops can usually be harvested each year. There are some named varieties. The roots are sometimes brought into a greenhouse in the winter and grown on there in order to produce an early crop of shoots. A deep-rooted and very long-lived plant, it dislikes root disturbance. The seed is dispersed by seawater, on which it can float for several days without loss of viability. A good bee plant.

An easily grown plant, succeeding in a good loam and an open sunny position but also tolerating some shade. Prefers a slightly alkaline soil in a position sheltered from strong winds. Tolerates poor soil and some shade. Dislikes acid and very stiff soils. Prefers a rich, well-drained very deep sandy loam and a pH of 7. Established plants are very drought tolerant.

Seed - sow March/April in a seedbed outdoors and either thin the plants out or move them to their permanent positions when about 10 cm tall. Plants can be cropped once they are more than 12 months old. The young plants are very attractive to slugs so some protection will often be needed. Germination can be slow so it is best to sow the seed in pots in a cold frame. Germination usually takes place in 3–26 weeks at 15°C.

Prick out the seedlings into individual pots as soon as they are large enough to handle and plant out into their permanent positions when they are at least 10 cm tall. Division in spring or autumn. Dig up the root clump and cut off as many sections as you require, making sure they all have at least one growing point. The larger of these divisions can be planted out straight into their permanent positions, though small ones are best potted up and grown on in a cold frame until they are

established. Root cuttings, 3 - 10 cm long, in spring. These can be planted straight into the open ground or you can pot them up in the greenhouse and plant them out once they are growing strongly. Plants can be used for ground cover when spaced about 60 cm apart each way.

PISONIA

Fig. 24e. Pisonia

Pisonia/Lettuce tree/Cabbage tree (*Pisonia grandis alba* R.Br.) belongs to the family Nyctaginaceae and the genus *Pisonia.* It is also known as cabbage tree, Moluccan cabbage. It is a small, evergreen foliage tree or a large shrub. The plant gives a feel of freshness. It is because of this that it is not grown for its flowers but for its leaves. It is also a salt resistant plant. The leaves are pale green and smooth with conspicuous veins and are crowded at the ends of branches. It has a dense foliage. The plant is rarely seen to flower. The flowers are small, green and inconspicuous. For better colorization of the leaves, it needs to be planted in a location which receives full sun for most parts of the day. It is a fast growing tree and if planted in the ground, it can reach heights of up to 5 m. In India the species, *Pisonia alba* is commonly grown. It is known as garden lettuce or tree lettuce. The light green colored leaves of the plant/tree are plucked and used for rheumatism. Young leaves of 'Alba' are a popular vegetable, rich in calcium.

RHUBARB

Rhubarb (*Rheum rhaponticum* L.) belongs to the family Polygonaceae and the genus *Rheum.* It is a perennial and is not commonly grown in India. Rhubarb originated from the colder parts of Asia, probably Siberia.

Rhubarb is grown primarily for its fleshy petioles, commonly known as *rhubarb sticks* or *stalks*. In culinary use, fresh raw stalks are crisp (similar to celery) with a strong tart taste; most commonly the plant's stalks are cooked and used in pies and other foods for their tart flavour. A number of varieties have been domesticated for human consumption. Rhubarb is usually considered to be a vegetable. Rhubarb is now grown in many areas and thanks to greenhouse production is available throughout much of the year. Rhubarb will grow year-round in warm climates. The colour of the rhubarb stalks can vary from the commonly associated crimson red, through speckled light pink, to simply light green. Rhubarb stalks are poetically described as *crimson stalks*. The colour results from the presence of anthocyanins, and varies according to both rhubarb variety and production technique. The colour is not related to its suitability for cooking: The green stalked rhubarb is more robust and has a higher yield, but the red coloured stalks are much more popular with consumers.

It is rich in vitamin C and contains traces of vitamins A and B_2. Rhubarb is a cool season, perennial plant that is very winter hardy and resistant to drought. Its crop is produced from crowns consisting of fleshy rhizomes and buds. The first shoots to appear in the spring are edible petioles and leaves.

PACIFIC WATERLEAF

Fig. 24f. Pacific waterleaf

Pacific waterleaf (*Hydrophyllum tenuipes* Heller.) belongs to the family Hydrophyllaceae, the genus *Hydrophyllum* and the species *tenuipes.* It is an herbaceous perennial plant native to western North America from British Columbia to northern California. The *Hydrophyllum tenuipes* plant spreads by rhizomes to form large colonies in wooded areas.

The flowers, leaves, stem, root and seed are edible. The root is cooked as a vegetable. The seed can be roasted and used as food.

Plants have a single flowering stem, 20 - 80 cm tall. Leaves are alternate and large, with blades up to 15 cm long and wide. They are hairy on both sides and divided into typically 5 pointed, coarsely-toothed segments. Flowers are in loose clusters, and are greenish-white to purple. Flowers are greenish-white to lavender, appearing in mid to late spring. Five conspicuous stamen extend beyond the five petals to a length more than twice as long as the petals. Sepals bristly on margins. The fruit is a capsule. Capsules have 1–3 seeds

PORTULACA

Portulaca (*Portulaca oleracea* L.) belongs to the family Portulacaceae, the genus *Portulaca* and the species *oleracea.* It is also known as verdolaga, little hog weed, purslane, garden purslane, pig weed, *kulfa, kulfa saag*. It grows wild in summer. It comes from tropical and subtropical region of the Old World. It has an extensive Old World distribution extending from North Africa through the Middle East and the Indian Subcontinent to Malesia and Australia. It has been used as a vegetable in India and Persia for over 2000 years. Purslane is cultivated as a herb in Asia and Europe. The diploid chromosome number is 2n=54.

Kulfa saag leaves and stems are glossy and slightly acidic. It is a fast growing herbaceous annual with thick, fleshy oval leaves. They are edible raw, preferably mixed with other greens because of their mucilaginous texture. They may be used as a thickner in soups. Cooked with onions and tomatoes, it makes a delicious dish. It is not very commonly used now. Its cultivation and use need encouragement. It grows like a wild weed and is a nutritious vegetable.

Purslane is rich in vitamin A, vitamin C and B vitamins. It is high in copper and iron. Leaves are much richer in vitamin C than stems, hence leaves should be

cooked briefly. Purslane has high oxalic acid content and should not be eaten in large quantities. Copper helps production of haemoglobin in co-ordination with iron. Vitamin A is necessary for good vision, good sight and healthy skin. it provides resistance to infections and protection against respiratory diseases.

Vitamin C is a superstar antioxidant. It protects against infections and promotes healing and saves from toxic effects of harmful chemicals. Vitamin C is essential for neutralizing free radicals. Free radicals, if not controlled, may lead to cancer. B vitamins are needed for normal functioning of our nervous system, healthy growth, healthy skin, nails and hair. They also help lower blood cholesterol, improve circulation of blood and production of red blood cells. Recent research has indicated that purslane's high levels of fatty acids may reduce chances of a heart attack and may stimulate our immune system. It is also a traditional remedy for dry coughs, swollen gums and when infused in hot water for blood disorders.

Two types are available under this group: (1) Common wild variety known as var. *oleraceae* (syn. *P. oleracea* var. *sylvestris*) and (2) Cultivated variety known as var. *sativa*; otherwise known as kitchen garden purslane. The latter is more upright and is considered better in quality and yield. The improved types have broad leaves. There are no improved varieties in this crop. Only local materials are used for cultivation of crop.

Portulaca is also cultivated to some extent. It is cultivated in plains from March-June and in hills from middle of April- middle of September. It can be grown in a variety of soil, but thrives best in rich loam. Seeds are mixed with sand and thinly broadcasted @ 2–3 kg/ha. The crop will be ready for harvest in 60 days after sowing.

The shoots grow erect when sown thickly. The succulent branches are cut when they grow 15–20 cm in length. The crop becomes ready for the first cutting in about a month after sowing. The plant gives 3–4 cuttings at fortnightly intervals.

The fruit is a capsule. Seed collection in this crop is somewhat difficult as the capsules break open. Therefore, the seed crop should be harvested when the early-formed capsules are fully developed. The plants are partially dried by spreading them thinly over a tarpaulin or gunny cloth. The stalks are then shaken to break open the capsules and the seeds gathered and cleaned for storage after drying and the seeds are collected after breaking them open

WATER AMARANTH

Water amaranth (*Alternanthera sessilis* Linn.) belongs to the family Amaranthaceae and the genus *Alternanthera.* It is an aquatic plant known by several common names, including sessile joyweed, Alternanthera, *ponnangannai* and dwarf copper leaf. It is used as an aquarium plant. The plant occurs around the world. The leaves are used as a vegetable. It is a small perennial herb propagated through soft wood cuttings. Young shoots and leaves are eaten as a vegetable in South east Asia. Occasionally it is cultivated for food or for use in herbal medicines.

This is a small annual or perennial herb with prostrate stems, rarely ascending, often rooting at the nodes. Leaves obovate to broadly elliptic, occasionally linear-lanceolate, 1–15 cm long, 0.3–3 cm wide, glabrous to sparsely villous, petioles 1–5 mm long. Flowers in sessile spikes, bract and bracteoles shiny white, 0.7–1.5

mm long, glabrous; sepals equal, 2.5–3 mm long, outer ones 1-nerved or indistinctly 3-nerved toward base; stamens 5, 2 sterile. In the wild it flowers from December till March. Alternantheras are hardy plants which stand trimming and can be propagated by cuttings or by division.

Aerva lanata is often mistaken for *Alternanthera sessilis*, which is also of the Amaranthecea family, and looks similar. On careful observation you will notice that flowers of *Alternanthera sessilis* are situated over the stem and their shape is round. As its flowers look like the eyes of a fish, *Alternanthera sessilis* is called *Matsyakshi*, fisheyed. Other Indian names of this plant are *koypa* (Marathi), *honganne* (Kannada). Leaves along with the flowers and tender stems are used as vegetable in Karnataka. It is diuretic, tonic and cooling. Juice of this plant, deemed beneficial to eyes, is an ingredient in the making of medicinal hair oils and *kajal* (kohl). The red variety of this plant is a common garden hedging plant, which is also used as a culinary vegetable. First clipping of tender leaves and stems can be done 45–60 days after planting.

PARSLEY

Parsley [*Petroselinum crispum* (Mill.) Nym.] belongs to the family Apiaceae, the genus *Petroselinum* and the species *crispum.* It originated from Central and Southern Europe. It is grown in a limited area in Himachal Pradesh, Punjab, Haryana, Uttar Pradesh and in high altitude areas of Southern India. It is a minor vegetable.

It is a herb used as a seasoning for many centuries. It is an herbaceous biennial with a long tap root cultivated for its leaves. Parsley is used as a salad and also for flavouring and garnishing. Its succulent smooth leaves are used to decorate or garnish meat and other dishes and in sand witches. It is also used in soups, sauces and stews.

There are three types of varieties. These are plain leaved, double curled and moss curled. In moss curled, plants are dwarf, compact and bushy. Its leaves are dark green with exceedingly fine cuts, serrated and deeply curled.

Parsley requires a deep soil well enriched with compost or manure and not acid and therefore a dressing of lime before seed sowing, or transplanting, is often desirable. Sowings may be made two or three times a year the best month being September and the seedlings progressively thinned to six or more inches apart; the thinnings may be transplanted, care must be taken not to damage the slender tap roots. Parsley may be grown with success in deep pots. When in the second year flowering shoots develop they should be cut off unless seed is required when the forms with the desired leaf shape should be selected. Seeds, if kept dry, will retain viability for about 3 years; they are slow to germinate.

It is mainly propagated by seeds. 250–300 g of seed is sufficient for one hectare. The seed of parsley is very small and germinates slowly. As parsley seeds germinate slowly (sometimes taking several weeks), it should be soaked in warm water overnight before sowing. Seeds can be sown in plugs or direct in pots, 4- 5 seeds per plug or 12 seeds per pot. It can be directly sown in the field or sown in a nursery bed during September-October. Seeds can also be sown outdoors in early spring in rows 25–30 cm apart, and cover 1.5 cm deep. Later thin the plants to

stand about 15 cm apart. Parsley plants should be spaced 22 – 30 cm apart. Seeds germinate in 21–28 days. Seeds per g varies from 650 –1,000 seeds. 6–8 week old seedlings are used for transplanting. Seedlings are planted at a spacing of 60 cm × 45 cm. Application of 15 t FYM, 65 kg N, 40 kg P and 25 kg K/ha gives better yields.

The outer and larger leaves are harvested first. The plants continue to give leaf cuttings for several months. It has average water needs. Water the plants at regular intervals, do not overwater. Parsley plants grow to a height of 30 – 45 cm. The leaves may be cut all season for use as needed. The following spring, remove the flower stems as fast as they appear so as to keep the plants producing leaves until those grown from a newly sown crop is ready. Manual harvesting is done to reduce the crop damage. Bunches of parsley plants are grouped by hand and the stalks are cut with sharp knife. Harvested leaves are sorted and tied in bundles, packed and marketed.

BLACK NIGHTSHADE

Black nightshade (*Solanum nigrum* L) belongs to the family Solanaceae, the genus *Solanum,* and the species *nigrum.* It is known as European black nightshade, black nightshade, duscle, garden nightshade, hound's berry, petty morel, wonder berry, small-fruited black nightshade or popolo. The berries are referred to as "fragrant tomato," or "*manathakkaali*" in Tamil, "*ganike gida*" in Kannada, and "*makoi"* in Hindi. Although not very popular across much of its growing region, the fruit and dish are common in Northern Tamil Nadu, Southern Andhra and Southern Karnataka. It is native to Eurasia and introduced in the Americas, Australasia and South Africa. In India, the berries are casually grown and eaten; but not cultivated for commercial use.

It is a nutritious leafy vegetable grown for its tender greens as well as small ripe fruits to be used in a dried form. Parts of this plant can be highly toxic to livestock and humans, and it is considered as a weed. Nonetheless, ripe berries and cooked leaves of edible strains are used as food in some locales; and plant parts are used as a traditional medicine. *S. nigrum* has been widely used as a food since early times, and the fruit was recorded as a famine food in 15th Century China. Despite toxicity issues with some forms, the ripe berries and boiled leaves of edible strains are eaten. The thoroughly boiled leaves- although strong and slightly bitter flavoured- are used like spinach. The ripe black berries are described as sweet and salty, with hints of liquorice and melon.

Black nightshade is a fairly common herb or short-lived perennial shrub, found in many wooded areas, as well as disturbed habitats. It has a height of 30 to 120 cm, leaves 4 to 7.5 cm long and 2 to 5 cm wide; ovate to heart-shaped, with wavy or large-toothed edges; both surfaces hairy or hairless; petiole 1 to 3 cm long with a winged upper portion. The flowers have petals greenish to whitish, recurved when aged and surround by prominent bright yellow anthers. The berry is mostly 6 to 8 mm diameter, dull black or purple-black. In India, another strain is found with berries that turn red when ripe. Sometimes *Solanum nigrum* is confused for deadly nightshade, *Atropa belladonna*, a different Solanaceae species altogether. A comparison of the fruit shows that the black nightshade berries grow

in bunches, the deadly nightshade berries grow individually.

It is propagated by seeds. Just like tomato seedlings it can be raised in nursery and transplanted in the field after 25–30 days of sowing at a spacing of 30 cm × 30 cm. The tender shoots with well developed leaves can be harvested 45–60 days after transplanting. Repeated cuttings can be taken 2–3 times per month. When the plants have become too old fruits can be collected to raise seedlings again.

WATERLEAF

Waterleaf/Ceylon spinach [*Talinum fruticosum* (L.) Jussieu; Syn. *Portulaca triangularis, Talinum crassifolium, Talinum triangulare*] belongs to the family Portulocaceae, the genus *Talinum*, and the species *fruticosum.* It is an herbaceous perennial plant that is native to Mexico, the Caribbean, Central America, and much of South America. It is also known as cariru, Surinam purselane, Philippine spinach, Florida spinach, potherb fame flower, and sweet heart. It is widely grown in tropical regions as a leaf vegetable.

It is a soft mucilaginous leafy vegetable grown in the tropics. The plant grows erect, reaching a height of 30–100 cm. The stem is stout, succulent and fleshy. The leaves are light green, shining, triangular in shape and fleshy. It bears small, pink flowers. The crop is highly self-pollinated. The diploid chromosome number is 2n=78, 72.

As a leafy vegetable, *T. fruticosum* is rich in vitamins, including vitamins A and C and minerals such as iron and calcium. Because it is high in oxalic acid, consumption should be avoided or limited by those suffering from kidney disorders, gout, and rheumatoid arthritis. It is cultivated in West Africa, South Asia, Southeast Asia, and the warmer parts of North and South America. There are no named varieties in this crop. Only local genotypes are grown for production of edible leaves.

The leaves and tender shoots are used as vegetables. Leaves are cooked, added to soups and stews. The high oxalic content of the leaf makes its consumption limited.

Well drained soil rich in humus is ideal. Being a shade loving crop, it is suitable for cultivation under crop canopy. It is easy to grow and propagate via seed or cutting, and it doesn't need that much space. It likes a lot of sun, though. It grows very well under shade. The propagation is possible through seeds and herbaceous stem cuttings. Cuttings are more common and used as seed materials. Rooted or unrooted cuttings can be planted at a spacing of 30 cm × 30 cm. Tender shoots and leaves are harvested 6–8 weeks after planting. In about 45 days, the harvest can be started and can be continued once in a month throughout the year. Yield of greens is 4000–6000 kg/ha.

KENAF

Kenaf/ Deccan hemp/Java jute [*Hibiscus cannabinus* L.; Syn. *H. sabdariffa]* belongs to the family Malvaceae, the genus *Hibiscus,* and the species *cannabinus.* In it is known as *gonkura* in Kannada, *gongura* in Telugu and as *gogu/palungu* in Tamil, *patsan* in Hindi, *machika, maryurika, ambika, sahasravatamulika* in Sanskrit. The name also applies to the fibre obtained from this plant. *Kenaf* is one

of the allied fibres of jute and shows similar characteristics. It is probably native to southern Asia, though its exact natural origin is unknown. The *kenaf* leaves were consumed in human and animal diets, the bast fibre was used for bags, cordage, and the sails for Egyptian boats. This crop was not introduced into southern Europe until the early 1900s. Today, principal farming areas are China, India, and it is also grown in many other countries such as the US, Mexico and Senegal.

The composition of *kenaf* leaves per 100 g edible portion is: water 79.0 g, energy 67,000 calories, protein 5.5 g, fat 1.2 g, carbohydrate 12.2 g, fibre 2.3 g, Ca 484 mg, P 18 mg, Fe 12.1 mg and ascorbic acid 75 mg. The composition of *kenaf* leaves is comparable to other dark green leafy vegetables.

The shoots or young leaves, and sometimes the flowers and young fruits, are used as a vegetable. The tender shoots and leaves are used as greens. Leaves have a slight acidic taste. As a vegetable it is widely grown in Africa, where it is grown on a much smaller scale as a fibre crop.

It is an annual or biennial herbaceous plant (rarely a short-lived perennial) growing to 1.5–3.5 m tall with a woody base. The stems are 1–2 cm diameter, often but not always branched. The leaves are 10–15 cm long, variable in shape, with leaves near the base of the stems being deeply lobed with 3–7 lobes, while leaves near the top of the stem are shallowly lobed or unlobed lanceolate. The flowers are 8–15 cm diameter, white, yellow, or purple; when white or yellow, the centre is still dark purple. The fruit is a capsule, 2 cm diameter, containing several seeds.

It is mainly propagated through seeds. Ridges and furrows can be formed at a spacing of 60 cm and seeds can be directly sown on one side of the ridges at a spacing of 30 cm. The tender shoots can be clipped 25- 30 days after sowing by which the branches can be induced. The tender leaves and stems are ground with green chillies and salt to prepare chutney.

INDIAN PENNYWORT

Indian penny wort/*vallarai* (*Centella asiatica* L.; syn., *Hydrocotyle asiatica* L. and *Trisanthus cochinchinensis* Lour.) belongs to the family Apiaceae/ Umbelhferaé, the genus *Centella,* and the species *asiatica.* It is also known as penny wort, *mandukaparni/jal brahmi* (Sanskrit), *ondelaga* (Kannada), *vallarai* (Tamil), Kodakan/kudangal/budhicheera (Malayalam), and *gota kola* (Sinhala). It is native to India, Sri Lanka, northern Australia, Indonesia, Iran, Malaysia, Melanesia, Papua New Guinea, and other parts of Asia.

Tender leaves and shoots are used as vegetable. A slight bitter taste is there due to the presence of a chemical known as "vallarine". In Malaysia they are steamed and eaten with rice. The leaves are fed to cows to increase milk yield and to poultry and rabbits in the Hawaii islands. The green leaves are found to improve the memory power of the brain cells, hence it is used as a medicinal herb in Ayurvedic medicine, traditional African medicine, and traditional Chinese medicine. *Centella* is used as a leafy green in Sri Lankan cuisine. Centella leaves are also used in sweet "penny wort" drink.

It is a small, herbaceous, annual plant. *Centella asiatica* grows in tropical

swampy areas. The stems are slender, creeping stolons, green to reddish-green in colour, connecting plants to each other. It has long-stalked, green, reniform leaves with rounded apices which have smooth texture with palmately netted veins. The leaves are borne on pericladial petioles, around 2 cm. The flowers are pinkish to red in colour, born in small, rounded bunches (umbels) near the surface of the soil. Each flower is partly enclosed in two green bracts. The hermaphrodite flowers are minute in size (less than 3 mm), with 5–6 corolla lobes per flower. Each flower bears five stamens and two styles. The fruits are densely reticulate, ribbed or warty fruit. The rootstock consists of rhizomes, growing vertically down. They are creamish in color and covered with root hairs.

Centella is commonly found as a weed in crop fields and other waste places throughout India up to an altitude of 600 m. It is also a water loving plant which trails as a vine in the soil surface. Propagation is through seeds or offsets. The plant grows well in moist sandy or clay soil, forming a dense green carpet. The soil should have more organic matter as well as more moisture always. It cannot tolerate moisture stress. The crop matures in three months, and the whole plant, including the roots, is harvested manually. •

CHAPTER 21

Cole crops

CROPS from the genus *Brassica* are sometimes called cole crops, which is derived from the Latin *caulis*, meaning *stem or cabbage*. *Brassica* is a genus of plants in the mustard family Brassicaceae (a large family of plants with four petaled flowers; includes mustards, cabbages, broccoli, turnips, cresses, and their many relatives). The members of the genus may be collectively known either as cabbages, or as mustards. Brassicaceae, the mustard family or the Cabbage Family includes the following species:

1. *Brassica juncea*: mustard greens.
2. *Brassica nigra:* black mustard.
3. *Brassica napus:* rape, Siberian kale, rutabaga.
4. *Brassica oleracea:* broccoli, Brussels sprouts, cabbage, cauliflower, collards, kale.
5. *Brassica rapa:* turnip, Chinese cabbage, Chinese mustard.
6. *Raphanus sativus:* radish, daikon.

Brassicaceae is made up of 3000 species in 350 genera. It is distributed throughout temperate parts of the World with maximum diversity in the Mediterranean region which has served as a point of origin for many weeds and cultigens of the family that are now widely distributed. Maximum diversity for this species centres around the Mediterranean and most species are found in the Northern Hemisphere. Another name for this family, which is also acceptable is Cruciferae.

Modern botanists have switched to Brassicaceae but since Cruciferae was so widely published it is one of the few plant families where both names can be used. Cruciferae refers to the cross like nature of the flowers, one of the easiest ways to identify this family. The ethnoflora includes structural variants of *Brassica oleracea* (cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, and kale) that represent a classic example of shoot polymorphism resulting from strong (human) selection. The storage or tuberous roots of radish (*Raphanus sativus*) are also important, as is the seed of several *Brassica* species for the production of spice (mustard) and oil. Members of the species Brassica oleracea have been selectively bred for different traits resulting in the foods we know as broccoli, kohlrabi, cabbage, kale, Brussels sprouts, and cauliflower.

CABBAGE

Fig. 25. Cabbage

Cabbage is probably the native of Western Europe and the northern shore of the Mediterranean region. All crops of this group (cabbage, cauliflower, knolkhol, sprouting broccoli, Brussels sprouts, etc.) have originated from a single ancestor *Brassica oleracea* var. *sylvestris*. It was in general use as early as 2000–2500 B C. Cabbage is an introduced vegetable crop in India, has adapted itself well and is now grown all over the country. It is the most common vegetable crop available during winter throughout India. In India cabbage is grown in an area of 3,90,000 ha with a production of 84,12,000 tonnes and a productivity of 21.6 tonnes/ha. The major cabbage growing states are, Uttar pradesh, Bihar, Assam, West Bengal, Maharashtra and Karnataka (NHB, 2011).

It is a rich source of vitamin A, B and C. It also contains phosphorus, potassium, calcium, sodium and iron. A 100 g edible cabbage contains 91.9% water, 4.6% carbohydrate 1.8% protein, 0.1% fat, 1% fibre and 0.6% minerals (Pal, 2004). It is known for medicinal properties in Ayurveda like use for cough, fever, skin diseases, peptic ulcer, urinary discharge and haemorrhoids. The heads vary from flat-topped to long-oval. Preference is generally given to varieties with compact, round heads though pointed head varieties are also grown. The tender leaves are primarily used as cooked vegetables, more in a raw form than in processed forms. In Hindi it is known as *Band gobhi, Patta gobhi.*

Botany

Cabbage (*Brassica oleracea* var. *capitata* L. f. alba DC) belongs to the family Brassicaceae/Cruciferae. The common cabbage grown in India is white cabbage. The red cabbage has the same botanical name except the form which is *rubra*, i.e. *Brassica oleracea* var. *capitata* L. f. *rubra* Thell. The Savoy cabbage is *B. oleracea* var. *sabauda* L. The red and the Savoy types are not so popular. It is a herbaceous annual for vegetable production, whereas for seed production it is a biennial. Cabbage is usually a temperate biennial crop, but tropical annual types are also available. It has bisexual flowers and the edible portion is made of thick overlapping smooth leaves covering a terminal bud, known as 'head'. The cabbage varieties differ in size, shape and colour of the head. The flowers are protogynous. Most of the varieties show self incompatibility. Somatic chromosome number is 2n=18.

Floral biology and nature of pollination: Cabbage is a temperate crop, thermoperiod is the most important factor for its flower induction. Most of the cabbage varieties are bred in the temperate region, tropical climate is not favourable for flower induction in cabbage. Cabbage requires vernalization for its flower induction. Therefore the biennial cabbage does not produce seeds in the tropical

and subtropical climatic condition of India.

Cabbage flowers are borne in terminal racemes which develop on the main stem and all its branches. The bright yellow hypogynous flowers borne on slender pedicels are perfect, regular, with four sepals, four petals, six stigma with a two-celled ovary containing many ovules per cell. The spreading terminal portion of petals form a cross which is the chief diagnostic character of the crucifereae. Cabbage is a cross pollinated crop, pollination occurs mainly through bees. Bumble bees are also some times observed. The pollen viability is dependant on temperature; 15°–20°C temperature is best for pollen germination. Temperature below 10°C and above 25°C hampers pollen germination.

Breeding

It is basically a temperate crop which does not produce seeds in the plains and hence no work either on breeding or on seed production has been taken up in the plains. It can produce only the edible heads in the plains, the seeds for which are produced in the temperate hilly regions. Their inheritance and hybrid vigour studies have been made on available genetic stocks. The resistance to black rot, *Xanthomonas campestris* was observed to be dominant and governed by polygenes.

The cytoplasm of 'Ogura' male sterile (MS) radish has been successfully utilized in cabbage. The nucleus of cabbage was introduced into the 'Ogura' cytoplasm of radish by backcrossing. Protoplast fusion of 'Ogura' cytoplasm, from broccoli is transferred to cabbage to produce hybrid seeds. The other two sources of CMS were from *Brassica nigra* [sterile] cytoplasm and sterile 'Anand' cytoplasm from *Brassica rapa*. The hybrids developed by CMS systems are now available for commercial cultivation in cabbage cauliflower. 'Dania' variety was developed as self compatible line for late season. Male sterility has been reported which may be used in the production of hybrid seeds. It was suggested to use the purple pigmentation in hybrid seed production of cabbage. In cabbage, almost all hybrids are exotic. The area under F_1 hybrids is 85% of the total area of cabbage in the country. Seeds of the exotic varieties Green Express and Green Boy are marketed by National Seeds Corporation (Nath *et al.* 2002).

Improved cultivars

I. Early Group *(maturity 55–70 days; weigh 0.8–2.5 kg)*

Copenhagen Market: Grown in limited area, large sized heads matures in 75–80 days.

Golden Acre: Selection from Copenhagen market with small round heads, compact, average weight 1.2 kg, fewer cup-shaped outer leaves. Maturity 60–70 days after transplanting. Yield 12.04 to 14.45 tonne/ha.

Developed by IARI, New Delhi.

Pride of India: Developed at Solan, selection from Copenhagen market, small round medium sized compact head, average weight 1.2–1.5 kg. Maturity 70 days. Yield 275–375 q/ha.

Pusa Mukta: Developed by IARI, Katrain. Flattish round medium sized compact head, average weight 1.4 kg. Resistant to black rot (*Xanthomonas campestris*). Puckered outer leaves. Maturity 70–80 days. Yield 275–325 q/ha.

II. Late Group *(maturity 85–130 days; weight 3–4 kg)*

Pusa Drum Head: Developed by IARI, Katrain. Plants with larger frame, large size flat shaped, less compact head, weighing 3.5–5 kg. Resistant to black leg (*Phoma lingam*) disease. Maturity 100 days. Yield 400–500 q/ha.

Variety September: Bluish green foliage and large sized frame. Oblong, large, very compact head, weighting 4–6 kg, resistant to cracking. Maturity 110 days. Yield 400–500 q/ha.

Late Large Drum Head: Wide frame, large sized medium compact head, weighing 3.5 kg. Maturity 115–120 days. Yield 350–500 q/ha.

Pusa Ageti: Developed by IARI, Katrain. Flattish round, compact, medium sized head, weighing 0.6–1.2 kg. Medium frame, green foliage, suitable for planting in March and August-September. Able to produce seed in northern plains of India. Maturity 70–90 days. Yield 100–300 q/ha. It a heat tolerant variety.

Hybrids

Presently about 30% area is under the cultivation of hybrids. Most of the hybrid seeds in India are imported by local companies and marketed under different brand names. Some of the hybrids are mentioned below:

Nath Laxmi 401: Released in 1993, marketed by Nath Seeds, has uniform compact heads with better shelf-life, yields 500–700 q/ha.

Bejo Sheetal 32: Released in 1992, it has round compact heads and yields 700–800 q/ha.

Green Express and Green Boy: Marketed by NSC, these have medium compact heads weighing 2- 3 kg and are popular throughout the country.

Pusa Sambandh: A synthetic variety developed from IARI, Katrain, has round compact heads, early, narrow frame, suitable for close planting.

Sri Ganesh Gol: Round, compact, bluish green head, weighing 1.5–1.8 kg with better staying ability after maturity. Maturity 75–80 days. Yield 300–350 q/ha.

Nath Laxmi 401: Round, very compact uniform sized heads, longer shelf life, weight 1.5–1.7 kg. Maturity 85–95 days. Yield 500–700 q/ha.

BSS-32: Very compact, round, large sized heads, weighing 1.5–1.8 kg, longer shelf life. Maturity 90 days. Yield 700–800 q/ha.

Quisto: Large sized frame, dark green foliage, very compact, large sized round head, weighing 1.6–1.8 kg. Suitable for early sowings. Maturity 110–120 days. Yield 700–800 q/ha.

Pusa Cabbage Hybrid-1: This is released by IARI, New Delhi.

KGMR-1(F1 hybrid): This is released by IARI, New Delhi.

Climate and soil

It is a cool season crop which thrives best in a relatively cool moist climate. It can withstand extreme cold and frost relatively better than cauliflower. It loses its flavour in dry warm weather. The optimum seed germination is obtained at 12.8–15.6 °C soil temperature. Cabbage can be grown on all types of soils from light to heavy soils. In clay loam or silt soils more yield may be obtained from the late crop. It does not grow well on a highly acidic soil and the maximum phosphorus availability to the plants is between pH 5.5–6.5. Higher acidity can be reduced

but it should not be reduced beyond 6.5 pH.

Cultural requirements

Since it is a cool season crop, the sowing is done in the plains usually in August, September and October for the early, main season and late group varieties, respectively. In some parts two crops of cabbage are taken.

An average of 500–750 g of seeds is required for planting one hectare. Sowing is done on the 15 cm raised nursery beds. The seedlings become ready for transplanting in 4- 6 weeks depending on the weather conditions.

The field is prepared by 3–4 ploughings. The early varieties are transplanted at a distance of 45 cm from row to row and 45 cm from plant to plant. The main season varieties are transplanted at a distance of 60- 70 cm from row to row and 45–60 cm from plant to plant.

It is a heavy feeder of nutrients especially of nitrogen and potash. 25 tonnes/ha of FYM, 100 kg nitrogen, 80 kg phosphorus and 80 kg potassium/ha is recommended. The complete dose of FYM should be incorporated in the soil at the time of field preparation. The entire dose of phosphorus and potash and half the dose of nitrogen should be mixed in the soil before transplanting. The remaining dose of nitrogenous fertilizer should be top dressed around the plants one month after transplanting.

Intercultural operations

Regular supply of moisture is necessary for the proper development of the heads. The first irrigation should be given immediately after transplanting. Head formation is the critical growth stage for water stress. Hence heavy irrigation is to be avoided at the time of marketable maturity of heads. Very shallow hoeing should be done in order to remove the weeds and loosen the soil for better aeration. In order to produce solid heads, the plants are earthed up after 5- 6 weeks of transplanting. The remaining dose of (50 kg N) nitrogenous fertilizer should be top dressed around the plants one month after transplanting.

Pest and disease management

Diseases

Damping off (Pythium* sp., *Rizoctonia* sp., *Fusarium* sp.*): It is a common disease in the nursery bed where the rotting starts in the collar region of the seedlings. In the nursery, it may be controlled by drenching the bed with 0.2% solution of captan 50 WP. The infection may also be reduced if the seeds are treated with captan @ 2.5 g/kg of seeds. Crop rotation with cereals is also recommended.

Bacterial black rot (Xanthomonas or Pseudomonas* sp.*): The margin of the leaves turn yellow. The veins become dark and vascular region of the main stem becomes discoloured. The cauliflower curds and cabbage heads get discoloured. The disease may be controlled to a great extent by following proper crop rotation. The hot-water treatment of seeds at 50°C for 30 minutes has given a good control. Wide spacing between rows and plants will reduce disease spread.

***Alternaria leaf spot and blight** (Alternaria* sp.*):* The small dark coloured spots appear on the leaves which spread rapidly to form circular lesions. In humid weather, concentric dark rings appear. In severe cases the cauliflower develops brown colour, whereas the cabbage develops black, moldy appearance after harvest. Cruciferous plants should not be included in the crop rotation. Seed treatment with captan @ 2.5 g/kg of seeds and spraying of captan[0.2%], or mancozeb 75 WP [0.2%] is recommended. The hot water treatment as in the case of black rot gives a satisfactory control of this disease.

Club root (Plasmodiophora brassicae): In severe cases malformed roots present a clubbed appearance. The foliage wilts on sunny days and recovers towards the evening. The infected plots should be abandoned for some time for growing cruciferous crops. The contamination of implements, farm animals, plants and surface drainage water should be avoided. Since the disease is prevalent in the acidic soils, efforts should be made to treat the seedlings before transplanting with mercuric chloride solution (1 g/l of water).

Black leg (Phoma lingam): The young plants in the nursery bed are affected usually. The fungus attacks at the base of the stem and roots and the plant wilts. The disease may be controlled by proper crop rotation, seed treatment by fungicides and hot water treatment.

Cabbage yellows (Fusarium* sp.*): The fungus enters the host through the root system and grows throughout the plant. The plants become yellow in two to four weeks. The growth remains stunted and defoliation occurs. No proper control measure is available; but in foreign countries some resistant varieties are available.

Mosaic viral disease: This is prevalent in crucifers. Young leaves show chlorosis and the older leaves would have vein banding. The virus is transmitted by aphids. Good weed control, avoiding growing of other *Brassica* spp in the crop rotation, spraying with dimecron or monocrotophos [0.05–0.1%] are the control measures.

Insect pests

***Aphids** [Brevicoryne* sp., *Myzus* sp., *Rhopalosiphum* sp.*]:* The greenish or black aphids damage the leaves by sucking the cell sap. Both nymphs and wingless adults suck cell sap from the leaves stem, and pods. Leaves become curly and pods are not produced. The affected leaves get curled and plants wither away and die. It may be controlled by the fortnightly spraying of malathion 50 EC @ 1 ml/l of water, but in case of light infestation the caterpillars may be hand picked and destroyed.

Tobacco caterpillar [Spodoptera litura]: This insect has became a devastating pest on cabbage and cauliflower. Cultural practices are collection and destroying the egg masses, ploughing the land before transplanting, installing pheromone traps [12/ha] and growing castor as trap crop along the borders. Chemical control measures are poison bait by mixing rice bran @ 10 kg with jaggery [1 kg] and methomyl 40SP @ 150 g to kill the hidden larvae. Spraying of indocacarb 14.5 SC @ 0.5 g/l of water is effective.

Diamond back moth (Plutella xylostella): The grayish caterpillars feed on tender plant parts and leaves and make short holes in the leaves. They also feed on heads of cabbage and cauliflower. For controlling this pest, Spraying of neem

seed kernel extract (NSKE) @ 4% at regular intervals is recommended. The IIHR has prepared soap from neem cake which is effect against this pest. Neem soap (1%) may be sprayed 20 days after transplanting and repeated four times at 10–15 days interval.

Mustard can be grown with cabbage/cauliflower to trap the insects. Grow two rows of mustard for every 25 rows of cabbage or cauliflower. Also two rows of mustard should be grown all along the border. It is better to sow mustard seed in one row 15 days before transplanting of the crop and in second row 25 days after transplanting. A maximum of nine paired rows of mustard may be grown in 100 m x100 m filed for obtaining economic yield.

Mustard saw fly (Ahtalia* sp.*): The adult is a minute black fly that lays eggs inside the leaf tissues. The caterpillar feeds on the leaves of young seedlings. This black caterpillar attacks almost all the cruciferous vegetables. It may be controlled by spraying of malathion 50 EC (@ 1 ml/l of water, but in case of light infestation the caterpillars may be hand picked and destroyed.

Cabbage butterfly (Pieris* sp.*): The young green caterpillars feed on the surface of the leaves and skeletonise them. In case of heavy infestation the leaves, tender shoots, flowers and fruits are completely destroyed resulting in the rugged appearance of the attacked plants. It may be controlled by spraying insecticides as used for controlling the mustard saw fly. After the head formation, persistant insecticides should not be used.

Semi looper (Plusia* sp.*): The green caterpillars, which are identified by the characteristic loop while moving, attack Cruciferous crops resulting in serious damage. The nature of damage and control measures are similar to those for cabbage butterfly.

Stem borer (Hellula undalis): In cabbage, the larvae of stemborer bore into central shoots. The infested plant does not produce the heads. Insecticidal spray of thiodan [0.2%] or fenvalerate [0.05%] at 10–15 days interval is recommended.

Root knot nematode (Meloidogyne* sp.*): Sometimes these minute worms become serious, causing retarded growth and improper development of curd or head. This may be easily identified by the formation of galls on the roots. It may be controlled by proper crop rotation with other crops.

Stunt nematode (Tylenchorhynchus brassicae): It has been found to reduce the yields of cabbage/and cauliflower in Uttar Pradesh It results in poor germination. Inter cropping of cabbage and cauliflower with margosa (*Azadarichta indica*) reduces the multiplication of the nematodes.

Harvesting and yield

The heads of cabbage should be harvested when they attain the full size depending on the variety used. They have a tendency to burst or loosen the leaves beyond the marketable stage. In the plains usually the heads are harvested from December to April. The early varieties take 60–80 days while the late varieties take 100–120 days for harvesting after transplanting. The early varieties yield lower than main and late varieties. However, the yields differ with the seasons, variety and location.

The yield of early cabbage ranges from 330–350 q/ha, while that of late varieties from 350–450 q/ha in northern India. It is at least 25% less in southern region, especially because the winter is mild and of shorter duration than in the northern region.

The marketable heads can be stored for four to five days under ordinary conditions, whereas they can be stored for several weeks in the cold storage at 0-1.7°C with 85–87% relative humidity.

Seed production

Cabbage requires a temperate climate and chilling for flowering and seed production. It produces only 'head' in the plains and fails to produce any flower and seed in the plains and hence its seed production is not relevant for plains. The seed production can only be done on hills where temperature remains 0°C for 2–3 months.

Cabbage seed can be produced either by the head-to-seed method or by seed-to-seed method. The former method is usually employed for biennial cabbage and to produce stock seed. The later method is often used for tropical annual cabbage which needs less or no vernalization and also to produce commercial seeds. Here the seed-to-seed production method is discussed.

Cabbage in general is very sensitive in its temperature requirement for seed production. Cabbage plants require vernalization for flower induction. For seed production of cabbage the time of planting is very important. The crop should be raised in such a time that the plants face lowest temperature at the head formation stage which facilitate quick vernalization. Longer cool season is also required for seed pod development. Such planting time will enable the plants to flower in December and pod development up to February.

Cultural practices for seed crop is similar to that for vegetable crop. The following aspects are to be taken care of while seed production is to be taken up:

Isolation: The isolation of seed plants for cabbage seed production is very important as cabbage varieties not only cross easily with one another but with the sub-species of *B. oleracea*. For the purpose of isolation in the seed production, crucifers are divided into two groups.

Cabbage, cauliflower, knolkhol, Brussel's sprout.

Radish, mustard, Chinese cabbage, turnip.

Varieties in each of these groups will cross readily with any other variety of the same kind of vegetables and any variety of any crop in the first group will cross easily with any other crop in that group. Natural crosses may also occur between the vegetables of the 2nd group, but such crosses do not occur as readily as in the 1st group. However, for the production of stock seed 1,600 m and for certified seed 1,000 m isolation is recommended.

Roguing: Off-type plants are removed at any time they are observed, but the general practice is to rogue the field at the time of head maturity so that the standard size, shape and firmness of the head is visible.

Head incision: When the cabbage head attains full maturity in December, head cut operation is necessary to help regeneration of the growing point of the core, i.e. facilitate the flower stalk emergence and development. The operation

may be done in the following ways:

Cross cut: Two cuts at right angles across the head up to the core so that the seed stalk may develop normally. Too deep cut may injure the growing point.

Side cut: In this system all sides of the head is cut up to the core so that the flower can initiate easily. After 5–7 days of incision seed stalk emergence will occur. The proper head cutting help the smooth emergence of the flower stalk by removing the binding leaves. Thereafter all the drying leaves are to be removed step by step.

Staking: The developing flower stalks need support. Stakes of about 2 m height is given to individual flowering plant.

Harvesting and threshing: Harvesting can be done when pods are brown. Too ripe pods dehisce. Seed should not crush or split when rubbed between the hands. The harvesting may be done in two lots. Generally the early plants are harvested first, when the pod colour of about 60–70% of the pods turn brown and the rest of the crop changes to a yellowish brown. After harvesting it is piled up for curing. After 4–5 days it is turned upside down and allowed to cure for another four to five days in the same way. It is then threshed with sticks and sifted with hand sifters. After thorough drying of seed in partial sun (up to 7% moisture content) it is cleaned and stored.

Seed Yield: The seed yield depends on prevailing temperature during the growing season, cool temperature during flowering and seed development results in higher seed yield. An average seed yield of 500–600 kg/ha is reported.

BRUSSELS SPROUTS

Brussels sprouts (*Brassica oleracea* var. *gemmifera* DC) (2n=18) belongs to the family Brassicaceae/Cruciferae. It is a temperate vegetable. The crop in the present form appeared in Brussels (Belgium) in 1750 and reached England and France in 1800 AD. However, the crop became popular in Europe and California in late eighteenth and early nineteenth century. The origin of the plant remains obscure and has been ascribed to both savoy cabbage and various forms of kale including head kale.

It is not grown on a large scale in India. Its cultivation is limited to areas around metropolitan cities like Delhi, Mumbai, Kolkata and Bangalore and in Himachal Pradesh, Jammu and Kashmir, hills of Uttaranchal, Kodaikanal, Nilgiris (Tamil Nadu) and Maharashtra. The mini heads or sprouts are sauteed or fried for use as vegetable.

Brussels sprouts is a cross pollinating biennial crop with natural pollination by honey bees. It has self incompatibility as mentioned earlier, besides self compatibility. The breeding procedures adopted include mass selection, pure line selection, family selection, half sib family selection, single seed descent, hybridization, pedigree selection and production of F_1 hybrids and synthetics. Anther culture has been successfully utilized for obtaining homozygous inbred lines. Improvement of Brussels sprouts by breeding has not been attempted in India. It is not possible to undertake its breeding in the plains because of its biennial habit and vernalization required for flowering and seed set. However, testing of varieties and selection were taken up at the IARI Regional Research Station,

Katrain, Kullu Valley (Himachal Pradesh).

Improved cultivars

Some varieties are dwarf and some are tall. Dwarf cultivars have short stem, mostly less than 50 cm in length. e.g., Improved Long Island, Early Morn, Dwarf Improved, and F_1 hybrid –Jab cross.

Tall cultivars are suitable for a longer season of growing. e.g., Evesham, Bed Fordshire, Cambridge No.1, Cambridge No. 3, Cambridge No. 5.

The variety 'Hilds Ideal' has been identified as suitable for growing in our country. Its plant grows up to 60 cm and produces 45–50 sprouts each weighing 7–8 g. The sprouts are compact and possess good flavour. A negligible percentage of loose sprouts at the base of the plant is also marketable. The yield per plant is 250–400 g in four pickings at an interval of 10 days. Delay in picking will lower the sprout quality.

Climate and soil

Brussels sprouts require cool season for its best performance. It is tolerant to frost. The sprout development is poor and inferior in quality when it is grown in summer or at high temperature. The optimum temperature requirement is 15–25°C. It is suitable for growing in a wide range of soils. Loam or sandy loam soil rich in organic matter and well-drained is ideal for this crop. The optimum soil pH is 6.0–6.8.

Cultural requirements

Seeds are sown during August-October in the northern plains and during February- April and June-July in the hills. Seeds are sown in nursery beds and later seedlings are transplanted in the field as in cabbage and cauliflower. About 500 g of seeds are required for planting one hectare.

The distance of planting is 60 cm × 45 cm. Soil should be incorporated with 25–30 tonnes/ha of farm yard manure. 100 kg nitrogen per hectare should be applied in equal splits, viz., at the time of planting, a few days after planting, after first picking and also after the second picking. Phosphorus and potassium are applied @ 50 kg and 20 kg per hectare, respectively, at the time of planting. Intercultural operations done to cabbage are applicable to this crop also.

Pest and disease management

As in cabbage

Harvesting and yield

Harvesting should be done 120 days after transplanting when the sprouts attain proper size and firmness. Regular and frequent harvesting should be done to avoid opening and yellowing of sprouts. Yield of large sprouted cultivars is about 100 q/ha of sprouts, while the other varieties yield 30–50 q/ha.

The sprouts cannot be stored for more than 2 or 3 days at room temperature. However, these can be stored for 3–5 weeks in cold storage at 0–5°C and 95–100 per cent relative humidity.

CAULIFLOWER

Fig. 26. Cauliflower

After originating in Cyprus, the cauliflower got established around Mediterranean region, particularly in Italy. Its further development and improvement were achieved in North and Northwestern Europe extending its cultivation up to 60° N latitude. The development of Indian cauliflower types made it possible to extend its growing area in the tropics and subtropics of the world. The crop is presently cultivated from 11° N to 60° N latitude. The different types of cauliflowers like Cornish, Northern, Roscoff, Angers and Erfurts originated from the Italians independently in different regions, *viz.,* Corinish and Northern in England, Roscoff, and Angers in France and Erfurts or Snowball in Germany and the Netherlands. Cornish type, perhaps the first to be introduced in India, has itself gone out of cultivation after contributing many genes to Indian varieties like resistance to black rot, self incompatibility, curd flavour, open plant habit, exposed yellow loose curds, etc. Cauliflower was introduced to India in 1822 by Dr Jemson at Saharanpur during the period of East India Company. After that it has undergone acclimatization and selection as a result of which the Indian cauliflower today has attained a characteristically different form compared to other temperate types of the world. The main differences are tolerance to high temperature and rainfall and earliness. In Hindi it is known as *Phool gobhi, Phul gobhi, Gobhi.*

In India cauliflower is grown in an area of 3,91,000 ha with a production of 73,49,000 t and a productivity of 18.8 tonne/ha. The major cauliflower producing states are Bihar, Uttar Pradesh, West Bengal, Assam, Haryana and Maharashtra (NHB, 2011). In India, it is grown throughout the country from 11- 35 ^{0}N latitude, the most important extensive growing locations are around Calcutta (West Bengal): Hajipur, Ranchi and Patna (Bihar and Jharkand); Varanasi, Faizabad, Lucknow, Aligarh and Meerut (Uttar Pradesh); around Delhi; Panipat, Sonepat and Karnal (Haryana); Ludhiana, Jalandhar and Amristar (Punjab); Ajmer, Ganganagar and Jaipur (Rajasthan); Kolar, Bangalore, Mysore and Hassan (Karnataka). Cauliflowers from Ranchi and Hajipur in Bihar are available as early as May. Besides, Snowball types are grown in hills of Himachal Pradesh, Uttar Pradesh and Uttaranchal, Ooty (Tamil Nadu) during summer months.

Cauliflower is cooked like cabbage, solo or in combination with peas, potato, etc. and is liked by both rich and poor. During glut period, when it is cheap, it is sun-dried for later use. It is used in pickles also. Cauliflower is rich in minerals like potassium, sodium, calcium, iron, phosphorus, magnesium. It also contains vitamin A and C. Fresh cauliflower per 100 g edible portion contains water 91.7%, protein 2.4 g, fat 0.2 g, carbohydrates 4.9 g, fibre 0.9 g, vitamin A 90 I.U, B_1 0.11, $B_6$0.2 mg, vitamin C 69 mg, citric acid 210 mg, nitrogen 16 mg, potassium 400

mg, calcium 22 mg, magnesium 7 mg, phosphorus 72 mg, sulphur 29 mg and 30 mg chlorine (Pal, 2004).

Botany

Cauliflower (*Brasssica oleracea* var. *botrytis* L.) belongs to the family Brassicaceae/Cruciferae and is a close relative of cabbage and knolkhol. Heading broccoli resembles with the late cauliflower except that the former requires chilling for seed production and the cauliflower does not. Cauliflower has longer and narrower leaves than the cabbage. Similarly, the cauliflowers differ from the sprouting broccoli in many contrasting features like; sprouting broccoli has wavy and shorter leaves, axillary sprouts and having apparent reproductive buds, while cauliflower has long and linear leaves, curd is the early stage of inflorescence development without any axillary sprouts. Cauliflower is very exacting in soil and climatic requirements. In cauliflower only the curd is harvested while in sprouting broccoli it is harvested along with the stem. The edible portion of plant is the 'curd', which is made up of numerous divided hypertrophic branches which terminate the main stem of the plant and is highly suppressed with no part of flower apparent there. It is herbaceous annual for vegetable production and biennial for seed production. Like cabbage, cauliflower is a temperate biennial crop and may require low temperature treatment for flower induction in late varieties. However, the Asian varieties are of annual type and can flower and produce seeds under tropical conditions. Somatic chromosome number is 2n= 18.

Floral biology and pollination: The floral parts are formed from the cauliflower curd, the inflorescence is shorter and more umbrella shaped than that of cabbage. There is an absence of central main stem above the point where branching begins. Other than this cauliflower does not differ with cabbage in respect of floral biology and pollination habit.

Breeding

Cauliflower is cross pollinated crop, in which pollination is done by insects and honey bees. To combat self incompatibility bud pollination procedure is adopted for self pollination. Cytoplasmic male sterility technology is same as that of cabbage. A few hybrids have been developed by utilizing self incompatibility and cytoplasmic male sterility. The F_1 hybrids cover 13% of the total area of cauliflower. 'Early' and 'Main Crop Patna' and 'Early' and 'Main Crop Banaras' were the first four listed Indian varieties, perhaps the earliest in the world and have greatly contributed for developing improved varieties adapted to hot-weather conditions in different countries, *viz.,* 'Pua Kea' in Hawaii, 'Compinus' in Brazil, 'Improved Japanese' and '96-D' in Israel and 'Extra Early' in Taiwan. Cauliflowers are classified into four distinct maturity groups.IARI has developed for the first time the synthetic varieties in Indian cauliflowers of maturity group II and III. An excellent genetic and breeding work at IARI has resulted in the development of some very high-yielding varieties like 'Pusa Deepali', 'Early Synthetic', 'Synthetic II', 'Line 328', 'Line 12C', 'Synthetic III', etc. Work taken up later at Pantnagar and Ludhiana is also quite appreciable. The other informations on Indian cauliflowers and Snowball type are also available (Nath *et al.* 2002).

Improved cultivars

I. Early group (May-June)

Early Kunwari: Curds are semi-spherical with even surface. Suitable for early July transplanting. Maturity 80–85 days. Yield 80–100 q/ha. A very early variety for growing in Punjab, Haryana, Himachal Pradesh and Delhi.

Pusa Early Synthetic: Developed by IARI, Katrain. Erect plants with bluish green leaves, curds small to medium in size, flat, creamy white and compact. Suitable for transplanting in July beginning. Adaptable to non-traditional areas like Karnataka and Kerala besides north Indian plains. Yield 110–120 q/ha.

Pusa Meghna: Developed by IARI, Katrain. Plants dwarf with medium sized sessile green leaves. Curds semi dome shaped, white, compact, medium sized, weighing about 350–450 g. Suitable for planting in the beginning of July. Maturity 90–100 days. Yield 125 q/ha.

Pant Gobhi-3: A synthetic variety having long stem, semi-erect leaves and hemispherical creamy white, medium compact, non-ricey curds. Suitable for planting in the beginning of July. Maturity 80–85 days. Yield 120 q/ha.

Pusa Deepali: Developed by IARI, Katrain. Plants medium tall, erect with bluish green and waxy leaves, curds compact, retentive, white and medium in size. Suitable for transplanting in the first fortnight of July. Maturity 110–120 days. Yield 200 q/ha. Recommended for entire north Indian plains.

Pant Gobhi-2: Developed by GBPUAT, Pantnagar. Curds are medium compact and yellowish. Suitable for transplanting in the first fortnight of July. Maturity 95–100 days. Yield 100 q/ha. Recommended for the northern plains of India.

Arka Kanti: Developed by IIHR, Bengaluru. It is a selection from local collection from Hazipur Bihar. It is an early tropical variety. It has white, compact curds. Duration 60 days. Yield 22–25 tonnes/ha.

Arka Vimal: This variety is released by IIHR, Bengaluru. Suitable for tropical conditions. Leaf orientation Semi-erect, narrow elliptic, dark green, glossy leaves. Average curd weight is 374 g. Curd yield is 187 q/ha in 75–80 days. Suitable for *kharif* and *rabi* seasons. Optimum temp range of 20–25°C. Moderately resistant to Alternaria leaf spot, downy mildew.

Arka Spoorthi: This variety is released by IIHR, Bengaluru. Suitable for tropical conditions. Leaf orientation Horizontal, elliptic, dark green, glossy leaves. Average curd weight is 332 g. Curd yield is 166 q/ha in 65–75 days duration. Suitable for *kharif* and *rabi* seasons. optimum temp range of 20–25°C. Moderately resistant to Alternaria leaf spot, downy mildew.

II. Mid early group (July-August)

Improved Japanese: Plants erect, leaves bluish green, curds compact and white. Suitable for transplanting by August end. Maturity 95 days. Yield 200 q/ha.

Pusa Hybrid-2: Developed by IARI, Katrain. Plants semi-erect with bluish green upright leaves and is resistant to downy mildew. Curds creamy white and very compact suitable for transplanting in the last week of August. Maturity 95–100 days. Yield 230 q/ha.

Pusa Sharad: Developed by IARI, Katrain. Foliage bluish green, leaf with narrow apex and prominent mid-rib. Semi-dome shaped, white and very compact curd. Suitable for August end transplanting. Maturity 80 days. Yield 240 q/ha.

Pant Gobhi-4: Developed by GBPUAT, Pantnagar. Medium long stem, semi-erect leaves; creamy white, medium compact, non-ricey, hemispherical curds. Suitable for August end planting. Maturity 75–80 days. Yield 140 q/ha.

III. Mid late group (September)

Pusa Synthetic: Developed by IARI, Katrain. A synthetic variety, plants erect, frame narrow to medium, curds creamy white to white and compact. Suitable for September end planting. Maturity 80 days. Yield 270 q/ha.

Pusa Himjyoti: Developed by IARI, Katrain. Erect bluish green leaves with waxy coating. Curds retentive white, self-blanched and solid, weigh 500–600 g each. This is the only variety, which can be grown from April to July in the hills. Suitable planting time is end of September. Maturity 75–80 days. Yield 240 q/ha.

Punjab Giant-35: Developed by PAU, Ludhiana. Plants vigorous with medium sized white, compact curds. Suitable for late September planting. Maturity 80–85 days. Yield 250 q/ha. Recommended mainly for Punjab and Haryana.

Dania: Successful in eastern hills. Plants sturdy with waxy leaves. Curds medium deep, white and very tender. Sensitive to weather conditions. Suitable for late September planting. Maturity 80–85 days. Yield 250 q/ha.

Pusa Kartik Sankar (F1 hybrid): This is released by IARI, New Delhi. Maturity September. Curd compact, retentive white, medium size, weighing about 475 g; resistant to downy mildew; average yield 149 q/ha. Maturity 95 days.

IV. Late group (October)

Pusa Snowball-1: Developed by IARI, Katrain. A late variety suitable for cool season where snowball group is grown. Leaves straight with self-blanching habit. Curds compact, medium and snow white in colour. Transplanting in late October to early November. Maturity 80–85 days. Yield 275–300 q/ha.

Pusa Snowball K-1: Developed by IARI, Katrain. Among snowball types, it has best quality curds, retentive snow white in colour. Leaves are puckered, serrated and light green in colour. Transplanting in late October to early November. Maturity 85–90 days. Yield 300–350 q/ha.

Ooty-1: Developed by TNAU, Coimbatore. Maturity 110–120 days. Yield 460 q/ha. Suitable for growing in hilly region of Tamil Nadu above 1800 m above/from sea level. Recommended by Tamil Nadu Agricultural University.

Pusa Paushja: This is released by IARI, New Delhi. Dec.-Jan. maturity, curd compact white. Average yield 400 q/ha. Maturity 75 days.

Pusa Shukti: This cauliflower variety developed by IARI belongs to December-January maturity group. It produces cream white compact curd weighing about 800–900 g with semi-blanching of inner leaves. It takes 80–85 days to reach marketable stage and duration of harvesting lasts for 14–15 days. It produces about 300–330 q/ha of curd yield. It is tolerant to downy mildew and black rot diseases.

Climate and soil

Cauliflower varieties are very much sensitive to temperature and photoperiodic requirements. It is, therefore, essential to choose the proper variety to be sown at the proper time. Cauliflower generally requires a cool and moist growing season. It cannot withstand so low temperature or so much heat as cabbage does. Dry weather and low humidity cause curds to be small and hard. For good seed germination, temperature of 10–21.1 °C is required. High temperatures produce poor quality curds like ricey, leafy, fuzzy, loose and yellow coloured ones. Temperatures below the optimum during growing period delays maturity, and undersized, small, unmarketable 'buttons' may be formed. The optimum monthly average temperature ranges from 15–25 °C for varieties of early-maturity groups for curd formation. The varieties of early maturity groups require higher temperature and longer day lengths. Cauliflower thus make heavy demands on the professional skill of growers, and its cultivation often fails under less favourable growing conditions.

It can be grown on a wide range of well drained soils. However, the early varieties prefer sandy loams, whereas for the late varieties loams or clay loams are preferred. It requires an average pH range of 5.5–6.6.

Cultural requirements

In the plains the seeds of early varieties of maturity group-I (a and b) are sown during May-June, maturity group-II (mid season) in July, maturity group-III (mid late) in August and maturity group-IV (Snowball type) during September-October in the well-prepared nursery-beds. The seedlings become ready for transplanting in about 4–6 weeks time.

As in cabbage the field can be prepared well with 3–4 ploughings. The seedlings are to be transplanted usually in the flat beds or on ridges at a distance of 45 cm × 30 cm in case of early varieties and 60 cm × 45 cm in case of medium and late varieties. The transplanting should generally be done in the evening for avoiding hot sun, and followed by light irrigation.

It requires an average of 500–650 g of seeds for the early varieties and 400–500 g for medium and late season varieties to raise the nursery for planting of one hectare of land.

Cauliflower is also a heavy feeder like cabbage. Depending on the climate and soil conditions, 20–25 tonnes/ha of farmyard manure (FYM), 100–120 kg N, 60–80 kg P and 80 kg K/ha is recommended (Swarup, 2006). The complete dose of FYM should be applied, and thoroughly mixed in the soil at the time of field preparation and the complete dose of phosphorus and potash and half the dose of nitrogen is applied before transplanting. The remaining half dose of N is applied in bands around the well established plants one month after transplanting followed by irrigation.

Intercultural operations

Intercultural operations are quite similar to that of cabbage. The curd is protected against sun burning and yellowing by covering the curd which is known as 'blanching'. In erect or semi erect plant types of late varieties the small terminal leaves cover the developing curd and protect it from the sun light. However,

some of the varieties retain white colour even if exposed to the sun. The remaining half dose of N is applied as top dressing in bands around the well established plants one month after transplanting followed by irrigation.

Physiological disorders

Whip tail: The blades of leaves do not develop properly and become strap-like. The growing point is severely deformed and no marketable curd is formed. This results because of the deficiency of molybdenum which occurs in acidic soils below 4.5 pH. It may also be controlled by the application of 1–2 kg/ha of sodium or ammonium molybdate.

Browning: It is common in cauliflower where the stem becomes hollow and the curd becomes brown because of the deficiency of boron. Later the edges of older leaves develop purple colour. It may be controlled by the application of borax (sodium tetraborate) @ 5–7 kg/ha in acidic soils and a heavier dose in neutral or alkaline soils.

Buttoning: This is identified by the development of small curd or 'button' while the plants are small and consequently the curd gets open. This is caused usually due to the deficiency of nitrogen, by planting older seedlings than 6 weeks, or any other factor that causes check in growth in early seedling stage. Some other factors may be insufficient moisture supply, water logging, hot and dry weather, carelessness in proper and timely weeding and pest attack. If an early variety is grown late, its growth is checked due to lower temperature and the curd remains undersized or 'buttoned'. Such factors should be avoided to get proper size of the curd.

Riceyness: The peduncle elongates and the curd becomes granular and loose. If late variety of cauliflower is planted early it occurs due to higher temperature. Rampant growth, heavy nitrogen dressing and high relative humidity also have unfavourable effect. It may appear when the harvesting of curds is delayed and they become over mature.

Blindness: In some cases the terminal bud does not develop or gets broken or eaten away by the insects. In other words, the plant grows without a terminal bud with no curd or head. The leaves become large dark green and leathery. These types of plants should be removed.

Pest and disease management

As in cabbage

Harvesting and yield

The heads of cauliflower should be harvested when the curd has attained the proper size, bright colour and compactness. The plant is cut off well below the curd so that the stub thus left protects the curd during transport. The early varieties take 60–80 days and the late varieties mature in 100–120 days. Yield of early varieties range between 300–450 q/ha while that of late varieties is about 700–800 q/ha.

The edible curds can be stored for 3–4 days at ordinary temperature, whereas it can be stored for 30 days at 0° C with 85–90% relative humidity.

Seed production

Like cabbage, cauliflower is very sensitive to temperature for flowering. The sowing time for cauliflower should be so adjusted that the plants have maximum leafy growth by December when the temperature goes down. Such planting time will enable the plants to flower in December and seed development up to February. Cultural practices for seed crop are similar to that for vegetable crop. The following aspects are to be taken care of while taking up the seed production.

Isolation: Sufficient isolation distance should be provided to the seed production field of this crop from fields of other cauliflower varieties as well as any other Brassicas. However, for the production of stock seed 1,600 m and for certified seed 1,000 m isolation is required.

Roguing: Careful roguing is essential for cauliflower seed production. Cauliflower varieties vary in their morphological characters, especially at the time of maturity. Therefore, off type plants should be rogued out to bring uniformity in the variety. The characteristic of the curd, such as size, colour, compactness and uniformity are considered while roguing.

Curd scooping: Scooping the central position of curd when it is fully formed helps in the easy emergence of the flower stalks. Scooping is essential in very compact varieties for easier bolting and early flowering, besides getting higher seed yields.

Staking: The flower stalks should be supported with stakes of about 1 m height to individual flowering plants.

Harvesting and threshing: Harvesting can be done when pods are brown. Too ripe pods dehisce. Seed should not crush or split when rubbed between the hands. The harvesting may be done in two lots. Generally the early plants are harvested first, when the pod colour of about 60–70% of the pods turn brown and the rest of the crop changes to a yellowish brown. After harvesting it is piled up for curing. After 4- 5 days it is turned upside down and allowed to cure for another 4–5 days in the same way. It is then threshed with sticks and sifted with hand sifters. After thorough drying of seed in partial sun (up to 7% moisture content) it is cleaned and stored.

Seed yield: Average seed yield of cauliflower is about 500–600 kg/ha depending upon the variety, extent of pollination and management practices.

It is possible to produce the seeds of the varieties of first three maturity groups, i.e. Indian cauliflower varieties in different parts of the plains. The usual method is to leave the plants with good curd in the field which later produces flower stalks and flowers and the seed ripens from March-May. But this method occupies lot of area because plants for seed production are left here and there in the field. It is recommended that the selected plants with best curds may be uprooted carefully and replanted in a compact block for seed production. In this process, before transplanting or at the time of transplanting, the curds of the stecklings are given scooping or incision in the middle of the curd to facilitate the growth of the side seed stalks which permit better quality seed production.

While transplanting, the stecklings may be spaced at 75 cm × 75 cm. It is necessary that the field is well prepared and manured before transplanting. The bee activities for efficient pollination should be encouraged. Use of insecticide

spray at the flowering time should be avoided. The seed gets ready from March to May depending upon the maturity group. It should be cured, threshed, cleaned, graded and stored before the onset of rains.

In early and mid season varieties (up to maturity group III) excellent seed set is observed in the plains and on an average, a seed yield of 500–650 kg/ha can be obtained. Early and mid season varieties like, Pusa Meghna, Pusa Early Synthetic, Early Kunwari, Pusa Deepali, Pusa Sharad, Improved Japanese, Pant Gobhi-2, Pusa Hamajyothi and Arka Kanti are recommended for seed production in plains. Late varieties like Pusa Snowball, Indian Snowball, Snowball-16, Dania, Dania Kalimpong and Ooty-1are recommended for seed production in hilly regions.

BROCCOLI

Fig. 27. Broccoli

Broccoli (*Brassica oleracea* L. var. *italica*) belongs to the family Cruciferae. In Hindi it is known as *Hari phool gobhi*. The broccoli grown in India is commonly known as the green sprouting broccoli. The other types of broccoli of northwestern Europe, Portugal and Italy, mainly biennials, are purple sprouting broccoli. In India broccoli is a recent introduction.

It is used as a sauteed or fried vegetable or as fresh salad. It is grown on a limited scale, mostly around metropolitan cities. Broccoli is an important health food as it has been found to be anti-carcinogenic and antioxidant. The name broccoli refers to young shoots which develop and it resembles cauliflower. The plants form a kind of head consisting of green or purple buds and thick flower stalks.

Improved cultivars

Pusa KTS-1: 85–95 days, early maturing in northern India. Developed by IARI, Katrain (HP).

Palam Samridhi: 80–90 days, early maturing in northern India. Developed by HPAU, Palampur (HP).

Palam Haritika: 145–150 days. Developed by HPAU, Palampur (Himachal Pradesh).

Palam Vichitra: Purple, 115–120 days. Developed by HPAU, Palampur (Himachal Pradesh).

Palam Kanchan: Yellowish green, 140–145 days. Developed by HPAU, Palampur (Himachal Pradesh).

The private seed companies are marketing seeds of many broccoli hybrids introduced from abroad like Premium Crop, Clipper and Green Surf.

Climate and soil

Broccoli is a cool season crop. Its cultivation is almost similar to late cauliflower varieties. It is grown from seeds in September-October and seedlings transplanted in October-November under north Indian conditions. An early crop of broccoli can be raised by sowing seeds in early August in a protected nursery bed and transplanting seedlings in late August or early September. The heads become ready for harvesting in 45–65 days after transplanting depending on the variety.

Another seed sowing can be done in early December in a protected nursery. The seedlings are transplanted during the second fortnight of January. In the spring-summer crop the broccoli heads are harvested in end of February-March.

The soil should have a high organic matter content and be friable. Broccoli can tolerate acid soils having pH of 6–6.8.

Cultural requirements

20–25 tonne/ha of farm yard manure is applied at the time of land preparation. 100 kg N, 80 kg P, and 60 kg K/ha is the recommended dose of fertilizers. Nitrogen is to be given in two split doses. 50 kg N, 80 kg P and 60 kg K/ha is applied as basal dose before planting. 50 kg N/ha is applied as top dressing after the first harvest.

The distance of planting between rows is 60–75 cm and between plants, 30–45 cm. The other cultural practices are almost the same as for cauliflower. The seed rate is about 400–500 g/ha and for direct sowing, the seed rate is 1–2.5 kg/ha.

Intercultural operations are practiced like other cole crops. 50 kg N/ha is applied as top dressing after 30 days of transplanting.

Pest and disease management

As in cabbage

Harvesting and Yield

The plant produces a large terminal head (300–500 g) and occasionally a few small sized lateral heads. Harvesting the central head is the common practice in this crop. It should be done at the correct time to avoid opening of buds. Heads are cut with a few leaves. The average yield is about 100–150 q/ha.

KNOL-KHOL

Fig. 27a. Knolkhol

Knolkhol or kohlrabi is reported to have originated in the coastal countries of northern Europe. It was introduced to India long time ago. Like cabbage and cauliflower, knolkhol is also cultivated commonly during winter in several parts of the country. In India, it is cultivated in northern parts of India (Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, West Bengal and Asom) and in some areas of

Karnataka and Tamil Nadu. However, its acreage is very limited.

Kohlrabi (German turnip) (*Brassica oleracea* Gongylodes group) (Ulkobi in Asomese and Bengali) is a perennial vegetable, and is a low, stout cultivar of cabbage. The name comes from the German *Kohl* ("cabbage") plus *Rübe ~ Rabi* (Swiss German variant) ("turnip"), because the swollen stem resembles the latter, hence its Austrian name *Kohlrübe*. Kohlrabi is a very commonly eaten vegetable in German speaking countries. In India, Kohlrabi is more commonly called *knolkhol* (English) or *nookal* (Hindi). In Kannada, kohlrabi is called *gedde kosu* or *navilu kosu*.

Kohlrabi can be eaten raw as well as cooked. It is also used extensively in Southern part of India. It is primarily used as a cooked vegetable. Its tuber is normally harvested for food, although in earlier strains the young leaves may also be cooked. The late varieties are sometimes used for animal fodder. It is high in minerals like calcium, magnesium, potassium, phosphorus, sodium and sulphur. It also contains vitamin A and C. A 100 g of edible portion contains 90 g water, 2.1 g protein, 6.7 g carbohydrate, 0.1 g fat, 292 mg potassium, 57 mg chlorine, 5 mg phosphorous, 40 mg calcium and 55 mg vitamin C (Arya, 2003).

Botany

Knolkhol or kohlrabi (*Brassica olearacea* L.var. *gongylodes* L.) belongs to the family Brassicaceae/Cruciferae and is a close relative of cabbage and cauliflower. It is a herabaceous plant of which the swollen stem just above the ground is the edible portion. The small leaves grow out on this stem arranged in a compressed spiral on the bulbous part. It is a temperate crop which produces edible vegetable as an annual in the plains and in the hills. For seed production it is a biennial in the hills.

Breeding

Knolkhol is a biennial and cross pollinated crop like cabbage and cauliflower with bisexual flowers. Since it fails to produce seeds in the plains, no effort was made either to maintain or to improve upon the available strains. It has cytoplasmic male sterility (CMS) with sterile Ogura cytoplasm from radish similar to cabbage or cauliflower. In India most of the varieties were introduced from European or American countries. The regional research centre at Katrain, Kullu valley [Himachal Pradesh] of IARI is the only centre, where knolkhol research is being carried out (Nath *et al.* 2002).

Improved cultivars

Palam Tender Knob: This is an early variety of knolkhol developed by CSK Himachal Pradesh Agricultural University, Palampur. This is recommended for all the agro climatic zones of Himachal Pradesh extending from subtropical low hills to temperate areas. Cotyledon colour of seedlings is light green; foliage formation of crown is weak; leaf attitude is erect, leaf blade size is medium; leaf shape is ovate with yellow green colour; it has small light green foliage and round flat light green knobs.

Large Green: This is a variety of knolkhol developed by CSK Himachal

Pradesh Agricultural University, Palampur. It is recommended for all the agro climatic zones of Himachal Pradesh extending from subtropical low hills to temperate areas. A late variety. Plants vigorous with dark green foliage. Knob flattish round, dark green. Maturity 60–65 days. Yield 140–170 q/ha. Adapted well in Himachal Pradesh.

Pusa Virat: This variety is released by IARI, New Delhi.

White Vienna: An early variety, plants dwarf with light green foliage and stem. Knobs are globular round and green with fewer leaves. Flesh creamy white, tender and crisp. Maturity 55–60 days. Yield 120–150 q/ha.

Early White Vienna: An early variety. Knobs are globular-round and green with fewer leaves. Flesh creamy white, tender and crisp. Maturity 50–55 days. Yield 110–130 q/ha.

King of North: It has dark green, flattish-round knobs. Dark green leaves are well spread over the knobs. Maturity 60–65 days. Yield 130–150 q/ha.

Early Purple Vienna: Early variety. Foliage purple, knobs globular-round, large, with purple skin and green flesh. Maturity 55–60 days. Yield 120–140 q/ ha.

Other varieties grown by the cultivators are 'Purple Vienna', 'Kyote No. 3'. The factors which determine the value of a kohlrabi variety are earliness, productivity and resistance to bolting.

Climate and soil

It is almost identical to that of cabbage. Varieties differ in their response to low temperature (below 10 °C) for premature bolting. Susceptible varieties, if exposed after germination to temperature below 10 °C, even for one week of low temperature, may produce bolting. High temperature after planting can delay the bolting of plants.

Cultural requirements

Knolkhol is also a cool season crop and is usually grown at the time when cabbage and cauliflower are grown.

The planting system is the same as that for cabbage where the seedlings are raised in the nursery bed from August to November and transplanted usually in the flat beds in the well prepared field.

The planting distance is 30 cm between the rows and 20 cm from plant to plant with in a row. It requires about 1.0 kg of seeds to raise the seedlings for one hectare of land.

25 tonnes/ha of Farmyard manure (25 tonne/ha) is incorporated in the soil at the time of field preparation. The 100 kg N, 60 kg P and 60 kg K/ha is recommended. Complete dose of P and K and half the dose of N (50 kg) is applied before transplanting as in cabbage.

Intercultural operations

It is the same as for that of cabbage and cauliflower. It requires frequent watering to establish the plants. If growth is slowed down or checked, the edible part becomes woody, tough and fibrous. At the same time, too rapid growth may cause

it to crack, especially when the initial growth was slow. The remaining half dose of N (50 kg) is applied as top dressing one month after transplanting.

Pest and disease management

As in cabbage

Harvesting and yield

The harvesting of knolkhol is made when it attains its marketable size (5–7 cm diameter) and bright colour depending on the variety. The harvesting should be done twice or thrice a week. At this stage the edible portion is tender and nonfibrous. For its marketing, the main root is cut off and the enlarged stem along with the leaves are tied up. The average yield is 200–240 q/ha depending on the region and the variety. Late varieties are usually higher yielding than early ones. Under ordinary conditions it can be stored for 2–3 days whereas under cold storage conditions it can be kept for relatively longer period.

Seed production

Cultural requirements for the seed crop are similar to that for vegetable crop. It is possible to produce the seeds of the varieties in different parts of the plains. The following aspects are considered while taking up seed production of knolkhol:

The seed is sown in the nursery from August. The seedlings are planted in the field during the first fortnight of September and the operation may continue up to the end of the third week. The crops planted during October and later, fail to form good knobs.

For transplanting, prepare the field well by ploughing and three to four harrowings before the seedlings are set in the field. Obtain breeder's/foundation seeds from sources approved by a seed certification agency. Seed requirement for late varieties is 375- 400 g/ha and for early varieties is 600–750 g/ha. The seeds are sown in raised nursery beds in a manner similar to that for cauliflower.

The seedlings 3–4 week old are transplanted. Transplanting should preferably be done in the evening and the field irrigated immediately afterwards. A spacing of 60 cm between rows and 45 cm between plants in a row is recommended. Extra application of nitrogen may be done before flowering, if necessary.

The crop requires a continuous supply of moisture. Therefore, the crop should be irrigated as frequently as required. Heavy irrigation should, however, be avoided when the heads have formed. A sudden heavy irrigation after a dry spell may cause bursting of heads. One hoeing and weeding during September-October, and one weeding and earthing up during November - December is required. Keep the crop clean till the spring when one more hoeing and earthing up is done.

Since it is cross pollinated crop, it is necessary to maintain an isolation distance of 1000 m between varieties to avoid contamination. Selection of knobs is done during February- March, when the knobs are well-developed. Only true to type plants are retained. Off types or diseased plants are removed.

Subsequent roguing is done at the flowering stage. The off type plants observed at the flowering stage are usually determined by the extent of branching of the flowering shoots. The higher the production of fully branched plants, the greater

is the seed yield. Therefore, care is necessary in nucleus seed production to select the right type of plants at flowering stage. Remove any undesirable plants. Subsequent roguing for off types, diseased plants affected by diseases such as phyllody, black leg, black rot, soft rot or leaf spot should be done from time to time as required.

Seed stalk elongation starts from March when the mean temperature rises. Flowering and pod formation starts during the first week of April. From 15 April to 15 May, the crop is in full flush of flowering and fruiting. The ripening of pods commences by 15 June to 20 June and the harvesting continues up to second week of July.

To avoid shattering of seeds, the whole crop is harvested in two or three lots with sickles. Generally, the early plants are harvested first and when the pod colour in about 60–70% of the rest of the crop changes to yellowish-brown it is harvested completely and piled up for curing. After 4–5 days, it is turned upside down and allowed to cure for another 4–5 days, in the same way. It is then threshed with sticks and sifted with hand sifters. After thoroughly drying the seeds they are cleaned and stored. The average seed yield is about 500–600 kg/ha. ●

CHAPTER 22

Salad crops

SALAD is a dish of raw leafy green vegetables or herbs, often tossed with pieces of other raw or cooked vegetables, or other ingredients and served with a dressing. e.g., lettuce. Some vegetables are consumed in the uncooked state and are known as salad crops. The knowledge of vitamin and mineral content in a number of green vegetables has made the use of salad crops very popular. The vegetables which are considered as salad crops are lettuce, celery, leek, parsley, endive, chicory, chervil, cress and water cress. All these are cool season crops and mostly quick growing. Only lettuce, celery and leek are grown on a commercial scale. The salad dish may include chopped-up carrots, radish, beet, tomato, broccoli, onion, or any other vegetable but the above crops from the main base of the dish.

LETTUCE

Fig. 28. *Lettuce*

Lettuce is probably a native of Europe and Asia Minor and has been in cultivation for over 2,500 years. It was grown by Persian Kings in 500 BC. Lettuce is grown in almost all the states of India. It is a popular salad crop mostly in cities. It is rich in vitamin A and minerals like calcium, phosphorus, sodium, sulphur, magnesium and potassium. It also contains protein, carbohydrates and vitamin C. According Chatfield [1949], 100 g leaves contain 94.8% water, 1.3% protein, 0.2% fat, 2.8% carbohydrates, 540 IU vitamin A, 8 mg vitamin C, 170 mg malic acid, 22 mg calcium, 0.5 mg iron, 25 mg phosphorus, 12 mg sulphur, and 39.74 mg chlorine (*Anon.*, 2011b).

Botany

Lettuce (*Lactuca sativa* L.) belongs to the family Compositae or Asteraceae. It is an herbaceous annual which produces seeds freely in the plains. It is an annual for leaf or head and is a biennial for seed production. It is a self pollinated crop having cleistogamous flowers. What most people call the seed is really a fruit, an 'achene', carrying pappus of fine silky hair. The calyx of the florets are modified

into a pappus with two or more teeth, scales or bristles and this is often involved in the dispersion of the seeds. As with the bracts, the nature of the pappus is an important diagnostic feature.

Cultivar groups of lettuce

Butter head: Butterhead lettuce forms loose heads of soft, tender, almost floppy leaves. The Boston variety looks a bit like a rose, while Bibb has a smaller head that looks a bit like a cup. The leaves have a buttery texture, which accounts for the name, and come in green, red, and bronze. The flavour tends to be sweet. e.g., Boston, Bibb, Buttercrunch, Cassandra, Fatima, Tom Thumb, Sangria.

Chinese lettuce: All the varieties of Chinese lettuce are quite bitter. They're stir fried or cooked in various dishes in Asian cuisine, and usually not eaten raw. A variety with a thick stem, and it appears this type is boiled and eaten like asparagus while the leaves are discarded. Most types seem to have long, sword-like leaves. e.g., Zulu, New Yu Mai, Yu Mai Tsai.

Crisp head: These are the guys with the crunch. Iceberg is by far the most common member of this group, and it dominates lettuce production in the U.S. Their leaves grow together in tight balls, while being very high in water, meaning you get a lot of green in a small growing space. e.g., Krachsalat, Iceberg, Great Lakes, Saladin, Webb's Wonderful, Crispsalat.

Loose leaf: The polar opposite of crisp head, loose leaf lettuce does not form a head, but just a loose bunch of leaves. The many varieties range dramatically in colour and shape. The leaves can be short, long, indented, and the plant itself can stick low to the ground like a short grass or be more bushy and upright. Loose leaf is also the best type for "incremental harvesting". Instead of harvesting the whole plant, you can pluck leaves off at the stem and they will grow back fairly quickly. e.g., Oak leaf, Grand Rapids, Ruby, Salad Bowl, Deer Tongue.

Romaine (Cos): With their long cylindrical leaves based upon a firm, juicy rib, the romaine types of lettuce are excellent for use as wraps. Leaves are generally green, but can be found in red as well. The name Cos originates from the Greek island of Cos or the Arabic word for lettuce, khus, depending on which expert you ask. They started being called romaine because they spread to western Europe from Rome. Romaine types of lettuce are also unique in that they are fairly heat tolerant, meaning they can thrive even in summer when other types are wilting. E.g., Little Gem, Winter Density, Bubbles, Lobjoits Green, Valmaine.

Summer crisp (French Crisp, Batavia): The Summer Crisp types of lettuce are, as their name implies, fairly resistant to summer heat. In appearance the heads are a bit like crinkly versions of the butterhead types, but the leaves have more of a romaine-like crunch to them. Summer crisp is pleasantly sweet and lacking in bitterness. e.g., Cherokee, Barbados, Nevada, Anuenue, Magenta.

The so called head, or crisp head lettuce is by far the most important type of lettuce Grown. This type produces firm heads, and has crisp leaves. Butter head or Boston lettuce tends to form smaller, less firm heads, with soft, waxy leaves. It is less well adapted to hot weather conditions. Loose leaf, or bunching lettuce does not form heads. The loose leaves are bunched for sale. Cos, or Romaine lettuce forms a more upright, loose head. It is much more resistant to cold than the other types,

and can withstand temperatures as low as –5°C without being damaged. The last three types mentioned, as well as red lettuce, have a more limited demand, and are grown on a small scale for local markets or in home gardens. These less common lettuces lend variety in salad bars and in home entertainment, and demand is growing.

Breeding

Since several varieties introduced from outside have performed well and the demand is not too high no serious efforts have been made on studying variation and gene action for further improvement of the crop. There are certain known heat resistant varieties available which need to be introduced and evaluated in India. Such varieties are 'Summer long Butter crunch' and 'Bibb (Butter head) and 'Green Ice' (Leaf). Some small varieties like 'Tom Thumb' (Butter head), 'Sweet Midget' (Cos) and 'Ruby' (leaf) should also be tried for growing in containers.

Climate and soil

It is a cool season crop, usually grown at the time when cabbage and cauliflower are grown. Lettuce is a cool weather annual crop which is not badly damaged by winter cold and light frosts, although differences in tolerance to cold (or heat) may vary appreciably among cultivars. Heavy frosts will, however, severely scorch the leaves, especially mature heads. It grows best under short day conditions, but the greatest demand is for use in salads during the summer. The most favourable temperatures for optimum growth and development are daily means between 15°C and 18°C, with monthly means between 7°C and 24°C. Day temperatures ranging from about 17–27°C, and night temperatures between 2°C and 12°C, are most suitable. Many cultivars will produce only small, inferior heads under hot summer conditions. Young plants, may also induce this annual crop to bolt, i.e. run to seed prematurely. Any growth stress, such as that caused by a lack of water, will intensify the problem of bolting. When a seed stalk starts to form in a head - it need not necessarily be visible - the leaves tend to develop a bitter taste.

The crop is fairly tolerant of soil type, and will do well on soils varying from light sand to heavy clay, provided the nutritional and water status is good. Best results are obtained on fertile loams, well supplied with organic matter. Soils which crust badly are less suitable, particularly when the crop is direct-seeded. The most favourable pH appears to be between 5.0–6,5. Whereas the deep, well-drained soils are suitable for most crops, including lettuce, the latter, with its shallow root system, can be grown quite successfully on relatively shallow soils, provided a favourable soil moisture regime can be maintained. It does best in sandy loam and silt loam soils, well supplied with organic matter. Where earliness is important, the sandy loam is preferred, but where earliness is not important silt loam is preferred.

Cultural requirements

Sowing time: In cold areas (heavy frost) sowing can be done during January - April, July – December; In warm areas (light frost) sowing can be done round the year; In hot areas (no frost) sowing can be done during February - August/

September.

Land preparation and sowing: Since it is a cool season crop, it is sown during September-November in the plains. It is sown in nursery beds where the seedlings get ready for transplanting in about a month. About 500 g of seeds are required for one hectare. The seedlings are transplanted 4–6 weeks after sowing in well prepared plots at the distance of 20–25 cm in the rows and the rows are kept 30-45 cm apart. The sowing is done in small flat beds but sometimes it is transplanted on ridges depending on the soil and the irrigation facilities. Sometimes it is sown directly in the fine beds in rows at 15–20 cm apart. The plants are thinned out to 3 cm when crowded. The sowing/transplanting of lettuce in hilly areas are done from March-June.

25 tonne/ha of farm yard manure is applied at the time of land preparation. Usually fertilizer requirement varies with the variety and soil type. 50 kg nitrogen, 60 kg each of phosphorus and potassium is applied as basal dose before transplanting. The crop is top dressed with 50 kg N/ha before the formation of heads.

Intercultural operations

Since it is a shallow rooted crop, shallow cultivation is recommended. In the plains, irrigation at frequent interval is essential for rapid development of leaves. Excess irrigation in heavy soils causes the rot and burning of leaf edges. A 2–3 year rotation is advocated to reduce disease build up. Few of the organisms causing diseases of lettuce attack other vegetable crops, so most other vegetables can be included in a rotation with lettuce. However, *Sclerotinium* rot can affect many vegetable crops and, should this be a problem, the choice of suitable rotational crops is more limited.

Pest and disease management

Diseases

Slimy soft rot (*Erwinia* sp.): This is a sort of bacterial rot which first appears as water-soaked, greasy, soft lesions, which spread rapidly and later turn dark brown and slimy. The disease causes considerable damage in head lettuce and can be controlled by the removal of the heads and also keeping the soil surface relatively dry.

Downy mildew (*Bremia lactuceae* Regel): The disease appears as light green or pale yellow lesions on the upper surface of the leaves. On the reverse side a downy white growth is seen. The lesions may join and eventually the entire leaf turns yellow and brown. The disease can be controlled by spraying or drenching the young plants with metiram 50 WP (0.2%).

Mosaic: Lettuce mosaic is a widespread seed borne and aphid transmitted virus disease and causes considerable damage. The leaves get destroyed by inward rolling and mottling. There may be severe stunting and the whole plant turns yellow and discoloured. Use of disease free seed and control of aphids is suggested.

Insect pests

Aphids (*Aphis* sp.): Aphids cause considerable damage to the lettuce crop.

The use of 3–4 per cent nicotine dust gives satisfactory control, if applied when the temperature is around 18–21°C. Spraying of insecticides like malathion or carbaryl (0.2%) is effective for control of this pest.

Harvesting and yield

The leafy varieties are harvested in 50–60 days when the leaves are immature and tender but large enough to use. In head varieties it is harvested on attaining a good size and solid head in about 60–70 days. The butter head and Cos types mature in 60–70 days, loose types take 40–50 days, while crisp heads mature in 80–85 days. While marketing, care should be taken so that no wrapper leaves are damaged. The fresh leaves cannot be stored under ordinary conditions because they loose their moisture very soon. However, the head lettuce can be stored for a few days under ordinary room conditions. Under cold storage conditions it can be kept at 0°C and 90–95% relative humidity for about two or three weeks. The average yield per hectare of head type ranges from 100–140 q (Sharma and Pandey, 1963).

Seed production

The early flowering varieties produce good seeds in the northern plains. It is a self pollinated crop with cleistogamus flowers but some amount of cross pollination has also been reported. It is suggested that the two varieties may be kept 50 m apart and 25 m apart for foundation and certified seeds production, respectively [Arya, 2003]. The agronomic practices to be followed are more or less the same as that of crop to be raised for the leaf or head production purposes. Harvesting for seeds should be taken up when a substantial number of heads have burst and shown the pappus which is in the form of white hair on the seeds and a good number of heads after opening have turned brown or dark brown but have shown out the pappus. White leaf type lettuce has no problem in producing flowering stalks. The outer leaves should be turned open by hand and provide a slight cut in head type for facilitating stalk to emerge easily. A seed yield of 400–500 kg/ha can be obtained.

CELERY

Fig. 29. Celery

It origins is in the eastern Mediterranean, and has been cultivated for over 2,000 years. There is likely to be an increasing demand for good quality celery because of the changing eating habits of the consumer towards healthful food. Celery is normally consumed fresh. In Hindi it is known as *ajmoda, ajwain-ka-patta.*

The petiole of the leaf is the main plant part consumed, and is long, thick, curved in cross-section, and longitudinally grooved on the outer surface. Leaf blades are used for soups, stews

and salads. The small white flowers are borne on a compound terminal umbel, developing in the second year of growth.

Celery stalks have only moderate levels of vitamins, but have a low percentage of carbohydrate and negligible fat. It is popular with dieters because it is 94% water and has only 21 calories/100 g portion consumed (comparable to energy stored in cucumber slices and lettuce). The leaves are hardly ever used, except in soups. Sliced stalks are also used as an ingredient in soup or stews. The main use of celery is as a salad dish. It is presented either diced or cut into small lengths. It is also served with other raw vegetables, such as carrot slices and broccoli florets, on a plate with various dips, as an appetizer at cocktail parties and other functions (Anon., 2011b).

Botany

Celery (*Apium graveolens* var *dulce* L.) belongs to the family Apiaceae/ Umbelliferae and the genus *Apium* Celery is related to such vegetables as parsley, carrot and parsnip. It is a biennial which is grown as an annual (a three-to-four month crop after transplanting), unless established for seed. The celery plant has a thick, fleshy taproot which may be broken off in transplanting. The plant develops a fibrous root system which is situated in the top 20 cm of soil. Leaves are pinnately compound with a characteristic smell when crushed.

Cultivars

Giant Pascal, Emperor of Jeen, Standard Bearer, Wright Grove Giant are a few introductions. The varieties recommended by IARI are Standard Bearer and Wright Globe Giant.

Climate and soil

Optimal conditions conducive to quick plant development and top yields of good-quality celery are moderately cool air temperatures (between 13°C and 24°C), adequate soil moisture without dry periods, and relatively high humidity conditions. Plants will withstand very light frosts, but are susceptible to colder conditions. Extended periods with temperatures remaining below 13°C will cause seed-stalks to be initiated (plant bolting). On the other hand, when maximum daily temperatures consistently rise above 24°C, the edible stalks become more fibrous, and tend to develop a bitter flavour. Sandy to heavier loam soils, which are slightly acid and rich in humus, are the most suitable for celery production. Although the plants are fairly shallow-rooted, the ideal soils are relatively deep, fertile, and well-drained soils in which moisture levels remain adequate.

Cultural requirements

The majority of celery plantings are established using seedlings, but if misting irrigation is available then direct seeding might be desirable. With direct seeding, weed control requires more attention. Between 0.5 and 1 kg fresh seed is required per ha of celery plants. Seed germination might often be a problem. Seed could be soaked in water for a day before it is sown, in order to hasten germination. Seedbeds should be level and standing water avoided. Young seedlings of about 45–60 days are to be used for transplanting.

Good yields require high levels of application of the major elements. Celery responds well to compost or organic manures. Compost in the root zone area of plants improve aeration and water-holding capacity; unfavourable growth conditions will affect stalk quality. 25 tonne/ha of farmyard manure, 100 kg N, 60 kg P and 40 kg K/ha are to be applied.

The field should be prepared thoroughly and the farmyard manure is to be incorporated in to the soil. 1/2 N and the entire quantity of P and K are to be applied as basal dose. In the field, single rows are commonly planted. Ridges and furrows may be prepared before transplanting. At 60 cm single row spacing, with 15–20 cm between plants in the row, a plant population of 85,000/ha will be achieved. With a double row bed system of planting, a spacing of 1 m from bed centre to bed centre is recommended, and two rows of plants about 35 cm apart would be established in each bed. This configuration, at a spacing of 20 cm within a row, would give a plant population of 1,00, 000/ha.

Intercultural operations

Growth checks through lack of moisture will result in lower quality of the succulent celery stalks. Because of its shallow root system, frequent, light irrigation is desirable, especially during the second half of crop growth. Nevertheless, prolonged periods when foliage is wet should be avoided, because such conditions favour development of foliage diseases. After transplanting, the plant forms a rosette of leaves on a short stem; succeeding leaves have elongated stalks which are increasingly fleshy. Thick petioles which are succulent and free of fibrous material should be aimed for at harvest. Any check to growth will favour development of the stringy texture in stalks. At the time of earthing up, the remaining quantity of N is to be top dressed. Weeds need to be controlled by mechanical working of the soil, or by manual weeding. Weed control, particularly when the crop has been direct seeded, but also in the early stages of growth after transplanting, is very important for this short-statured crop.

Soil moisture is one of the most important factors that determine the success of lettuce production. The moisture requirements of the crop are high, and no more than 50% of the available water in the root-zone should be depleted before an irrigation. The greater proportion of the roots penetrates the soil to a depth of only 30 cm, which infers that the nutrient and water requirements of the crop should be confined to this relatively small volume of soil. Wetting the soil to a greater depth is wasteful of water, and will also lead to higher losses of nutrients by leaching. The amount of available soil moisture to a depth of 30 cm is relatively small, and varies from about 1.8 cm, on very sandy soils, to about 5.0 cm, on very heavy clay soils. This implies that more frequent, but lighter, irrigations are necessary for lettuce than for many other vegetable crops. Such frequent irrigation favours the development, especially in summer, of several of the diseases.

Whilst green celery is the most popular type on the market, there is still a demand for blanched celery. "Blanching" is the process whereby sunlight is excluded from the developing petioles, and the formation of chlorophyll, which gives green colour to the stalks, is inhibited. The pale stalks may be more tender, and have a milder flavour than do the green petioles. Blanching is commenced

during the second half of growth, when plants have reached a height of at least 25 cm. Sleeves of bottomless pulp cardboard (similar to those protecting bottles) are slipped over the plant, or boards 20 cm or more wide, or opaque plastic sheeting, erected on either side of a row of plants, ensure that petioles of plants remain in the dark or in dense shade. So-called self-blanching cultivars, whose petioles are naturally a light yellow to yellow green colour, are also grown. They may be blanched further, by excluding sunlight from reaching the petioles. This produces a milder flavour. However, these types generally have fewer petioles per plant, and thus do not have the same compactness nor heart development, as do the commercial green celery cultivars.

Physiological disorders

Black heart: This results from calcium deficiency. Young heart-leaves of a plant develop dark water soaked tips, and the affected areas turn black as they dry. The condition is caused by low calcium levels in the soil, or by reduced uptake of calcium by the plant because of moisture stress or high levels of potassium or soluble salts. It can occur when the growth rate of young leaves is faster than the uptake of calcium by the plant's roots. Blackheart can be prevented by spraying calcium, as the chloride or nitrate salt, directly onto the heart leaves. Between five and ten kg of the salt in 1000 litres of water is applied per ha, and can be repeated at weekly to ten-day intervals. Soil application of calcium will not correct the condition once it appears. A condition known as cracked stem is caused by a deficiency of boron. Symptoms of the condition are longitudinal brown streaking on the inner surface of petioles, and cracks along the ridges of the outer surface. Expression of the symptoms of boron deficiency is often encouraged by the presence of excessive nitrogen in the soil and the plant. A deficiency of magnesium is expressed by chlorosis or yellowing, especially on leaf tissues between the veins, of older leaves. A spray application of one per cent magnesium sulphate (Epsom salt) should correct the condition; the application can be repeated to foliage about ten days later.

Pest and disease management

As in carrot

Harvesting and yield

Depending upon the cultivar and the season, harvesting should commence from less than three months to more than four months from the time of transplanting. Stalk or petiole size increases with time, but defects such as development of fibrous tissue will also become more marked. Thus there will be an optimal time for harvesting as heavy a crop as possible which is a high quality product for the consumer. A uniform planting would be expected to attain this stage, and to be completely harvested within a period of a week to a fortnight from the first plants being harvested.

Head lettuce is harvested when the heads are fully grown and firm. The loose-leaf types are harvested when the leaves have attained the required size. Under warm growing conditions the crop may be ready for harvest within 11–13 weeks

when direct seeded, or at 7- 9 weeks from transplanting. Under cooler growing conditions, or with late-maturing cultivars, the growing season may be extended for a further 4 or 5 weeks. In harvesting, the plants are cut off just above the soil surface to retain most of the wrapper leaves around the head. Loose, discoloured, damaged or diseased leaves are removed, and the butt ends cut cleanly for packing. To obviate damage by excessive handling, they are often packed into the marketing crates or cartons directly on the land, but they may be transported to a packing shed for packing. Usually 2–4 picks, over a period of 10–20 days, are necessary to gather the crop. It is most important to grade the heads by size, with each size grouping being packed separately. Lettuce of good quality is firm, fresh, clean and crisp, and free of any signs of wilting, seeding or bitter taste. A mean yield of 20–25 tonnes/ha can be expected under normal growing conditions.

Plants are usually lifted by hand, but machine harvesting may be used. A knife is used to separate roots from the butt, or base of the stem, and for trimming off older, outer stalks, and topping the heads, to remove the upper portion of leaves. Under very hot conditions, plants should be removed from the field as soon as possible to reduce wilting, and trimming can proceed in a shady structure. In most operations, washing to remove all traces of soil is necessary. Wilting is an important factor. Washing should assist in cooling the harvested celery, especially if the water is pre-cooled. A fresh appearance is very important in celery marketing. The average yield is 250–300 q/ha of celery. A good yield is considered to be 800 q/ha.

Seed production

Celery is a biennial crop and the seed is produced in hills. The crop is ready for harvesting when umbels turn light to dark brown in colour during later part in the month of March. The fruits mature by early April. The crops are harvested when 80% of the umbels turn light brown in colour. The plants are cut at ground level in early morning hours by sickle to avoid seed shedding. The crop is stalked and allowed to dry over threshing floor for a few days. Thereafter it is threshed, winnowed and graded with the help of sieves. The seed is further dried and stored in cool dry place. The yield is 1000–1300 kg/ha. The seed can be stored for 1–3 years without much loss in oil content and oil quality.

LEEK

Leek (*Allium porrum* L) belongs to the family Amaryllidaceae (formerly family Alliaceae) and the genus *Allium.* It is supposed to have had its origin in Mediterranean region. Leek is believed to have developed from field garlic in Eastern Mediterranean and the Middle East. It has been grown since ancient times in Egypt and was also eaten by the Greeks and the Romans. It has been mentioned in the Bible along with onions and other alliums. Presently it is grown throughout the Western World and especially valued as a soup ingredient. It can be cooked in many ways. It needs thorough cleaning before use as it lurks sand and grit in between the leaves. Leeks have no bulbs, only tall thick stalks, wrapped one over the other. Only white parts are eaten. They are very flavourful. They are suitable for eating raw, sautéed, boiled or cooked as a side dish. It may also be used as

garnish for soups or cooked in stews and casseroles.

It is a non bulbing biennial grown for its blanched stem and leaves to be taken as salad or cooked with other vegetables or used in flavouring soups. The long white stem and leaf base and green tops which are edible are good sources of carbohydrate (5%), protein (1.8%), phosphorus (70 mg/100 g), iron (2.3 mg/100 g) and Vitamin C (11 mg/100 g). Like all other alliums, leeks are rich in potassium, calcium, phosphorus, iron, vitamins C, thiamin (B_1), and riboflavin (B_2) and are very therapeutic. They are usually more expensive than other members of the family. Leek contains allicin and diallyl disulfide, that block or suppress cancer causing agents, boost immunity and prevent infections.

Cultivars

A few introductions like London Flag, American Flag and Elephant, perform well under Indian conditions.

Climate and soil

It is a cool season crop. However, it can tolerate heat more than onion. It thrives best in a temperature range of 12–18°C. Medium soils which are rich in nutrient and organic matter with a pH range of 6–8 are the best suited.

Cultural requirements

Leek is normally propagated by seeds which are sown during August-October in the nursery bed. The seedlings will be ready in 40–45 days after sowing when they attain 15 cm height. About 5–7 kg of seeds would be required to raise seedlings to plant one hectare.

Narrow trenches (30 cm deep) are formed in the well prepared fields which were supplied with 20 tonnes/ha of FYM. The seedlings are planted with a spacing of 30 cm × 10 cm. Just before planting the seedlings, a quantity of 50 kg of N, 65 kg of P and 130 kg of K/ha is applied as band application and mixed with the soil.

Intercultural operations

The trenches are irrigated just before planting and the seedlings are planted at the centre. Life saving irrigation is given on the 3rd day and subsequent irrigations are given once in 7–10 days. Weeding and hoeing are done as and when necessary. Blanching is an important operation in the cultivation of leek. The trenches in the centre of which the seedlings are planted are filled up with top soil, thereby the plant bases are earthed up. This makes the base blanched. The earthing up is continued as the plants grow. The top dressing is done with another 50 kg of N, 30 days after planting.

Pest and disease management

The pests and diseases are more or less the same as that of onion except a disease called 'white tip' of leek which does not affect onion. This is caused *by Phytophthora porri* and can be controlled by spraying 1% Bordeaux mixture.

Harvesting and yield

Just like green onion, leek is harvested and kept under shade in cool condition. A quantity of 200–250 q/ha can be harvested in a crop duration of 70–85 days.

BABY CORN

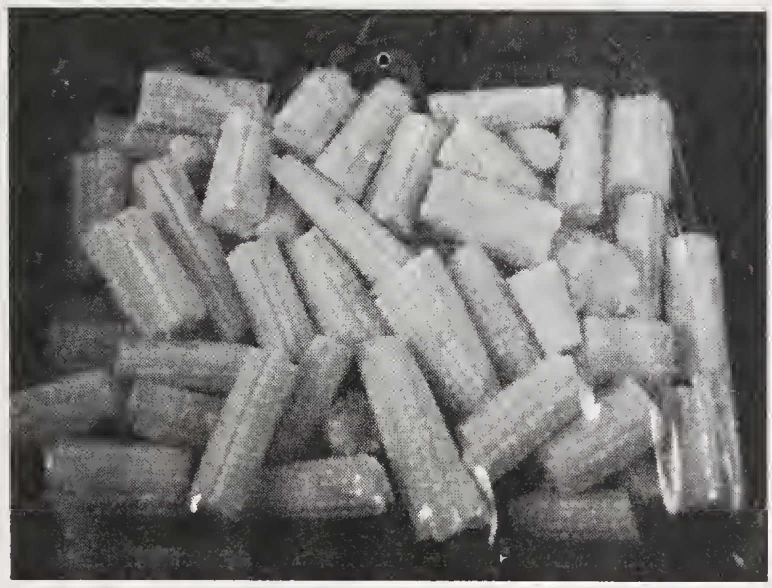

Fig. 30. Baby corn

When Columbus discovered America in1992, maize was already cultivated in American continent, indicating its antiquity. It is a staple food crop of the indigenous people of Mexico, Central and South America, supporting its origin in this region. But it spread from America to Spain, Portugal, France, Italy, Europe, North Africa and India. With the existence of *murli* subrace of popcorn in Sikkim, Bhutan and other north Eastern states which resemble the primitive hypothetical maize gave another thought of origin. It is believed that Sikkim and other north eastern states to be the secondary centre of origin of maize, however the recent evidence show the possibilities of its pre Columbus introduction through the Atlantic Arabian route. From India it went to china and later it was introduced in Philippines and East Indies. Now it is being grown in USA, China, Brazil, Argentina, Mexico, France, South Africa, Russia, Romania, Yugoslavia and India. Sweet corn is extensively cultivated in the USA, Canada, South America, France, China and Australia.

Maize (*Zea mays* L.) had been cultivated for grain and fodder purpose. It is used both as food for human and feed for livestock especially in poultry industries. It is the third most important cereal crop next to rice and wheat in India and also a predominant cereal in global agricultural economy. It has got immense yield potential and is therefore called as "miracle crop" and also "queen of cereals". Maize being a C4 plant is an efficient convertor of nutrients into food.

In the recent years, baby corn maize has gained popularity as valued vegetable throughout the world including in India. Cobs removed within 3–5 days after their emergence are called baby corns. It can be eaten raw and included in diet in number of ways as salad, chutney, vegetables, pickles, kheer, chinese preparation, in preparation of spicy foods, soups, pulav etc. Baby corn ears can be canned in two % brine solution. Pickles and canned baby corn ears have great potential for export in the western markets round the year.

India has emerged as one of the potential baby corn producing country because of the low cost of production as compared to many other countries. Nutritive value of baby corn is comparable with several high priced vegetables. It is rich in phosphorus (197.89 mg/100 g) in comparison to 21–57 mg/100 g phosphorus (P) content in other common vegetables. It is an attractive low calorie vegetable, high in fibre and without cholesterol.

Baby corn fresh picked is sweet, juicy and crunchy. One can eat it whole out

of hand— kernels and cob together. It can be added raw to salads, or cooked quickly in stir fries. Baby corn is the finger-length corn that most often shows up in dishes. It looks like miniature corn on the cob. But baby corn does not come from dollhouse-sized (miniature sized) corn plants; baby corn is harvested from standard varieties of sweet and field corn just after silking.

Baby corn is a relatively new vegetable. Tender and sweet baby corns are often used in dishes and salads. Raw baby corn can be added to a green salad or mixed fresh-picked with other vegetables. Baby corn can be roasted lightly with sesame seed oil and tossed in a salad. Cobs whole or cut on the diagonal can be added to soups.

Baby corn is the tender cob of the specific group of maize plants and it is harvested when the silks have just emerged (1.3 cm) before fertilization. The tender cobs are dehusked and used as salad vegetable. The cobs have 6–7% starch, 1.3% sugar (*Anon.*, 2011b).

Botany

Baby corn (*Zea mays* L.) belongs to the family Poaceae/Gramineae. It is a speciality or sugary form of the common corn. It has one or more genes that retard the conversion of sugar to starch in the endosperm. Sweet corn is a monocot, monoecious, annual and highly cross pollinating. Like field corn it has a terminal staminate inflorescence, known as tassel, and pistillate inflorescence is the ear (or cobs) with thin thread like stigmas (silks) protruding from the tip of the ear. The sweet corn has increased sugar and decreased starch in the endosperm with thinner pericap which impart it flavour and soft texture of endosperm. The kemel colours are white, yellow or bicolour in different varieties or hybrids. Corn is a diploid with chromosome number 2n=20.

Breeding

In India, breeding of sweet corn is almost negligible, though extensive work has been done on the improvement of field corn in the country. Very few improved cultivars and hybrids of sweet corn are grown for commercial cultivation. In India sweet corn and baby corn are grown on a limited scale.

Improved cultivars

Short duration, prolific, single cross hybrid with medium height should be selected. A few varieties suitable for baby corn production are as follows:

Short duration, prolific, single cross hybrid with medium height should be selected. A few varieties suitable for baby corn production are as follows: Vivek Maize Hybrid 23, Vivek Maize Hybrid 25, HM-4, Hybrid maize 5, Pusa Extra Early Hybrid maize 5, HIM 129, Prakash, DHM 109, VL Makka 42, MTH-14, RCM 1-1, RCM 1-3, Golden baby and MLY.

Two varieties of corn, VL-42 and MEH-14 developed at IARI, New Delhi are suitable for production of baby corn. The composite culture, namely, COBC-1 developed by Tamil Nadu Agricultural University, Coimbatore, is a baby corn variety.

Any variety of sweet or field corn can be grown for baby corn harvest. Some

corn varieties are suited for baby corn harvest; these varieties never gain more than 2 m in stature. 'Little Indian', 'Baby', 'Golden Midget' (butter yellow kernels), 'Glacier' (white kernels), 'Miniature Hybrid', 'Baby Asian', 'Baby Blue' (blue kernels), Bo Peep ('pink kernels'), and 'Strawberry Popcorn' varieties can be tried.

Climate and soil

It is a warm season crop but can be grown under different climate conditions, from tropical and subtropical to temperate regions. It can be grown at temperatures between 10–40°C but the best temperature for its plant growth is 21–30°C. In India corn in cultivated in almost all parts of the country. Sweet corn requires fertile and well-drained soil ranging from deep clay to light sandy loam with optimum soil pH 7.5–8.5.

Cultural requirements

Cultivation practices of baby corn are similar to that recommended for normal corn production with only exception is the duration of the crop, which is approximately 60 days as compared to 110–120 days in case of grain crop.

Sowing time: Baby corn can be sown throughout the year under irrigated condition while for a rainfed crop, sowing during the onset of Southwest monsoon (June - July) or Northeast monsoon (September- October) would be ideal.

Land preparation and sowing:The field should be prepared by ploughing 2–3 times. About 25 tonne/ha of FYM should be applied to the soil at the time of last ploughing. Seeds of corn are sown on ridges. A row to row spacing of 45 cm and a plant to plant spacing of 15 cm within the rows can be followed. A population of 1,00,000–1,10,000 is sufficient for better yield of baby corn. For this quality seed should be selected and used @ 18–20 kg/ha.

A basal dose of 20 kg N, 60 kg P and 40 kg K/ha should be applied in the rows just before the seeds are sown and covered with soil.

Seed sowing is done by ridge and furrow method, generally sowing is done on southern side of the ridge by dibbling to a depth of 4 cm along the furrow in which fertilizers are placed. Seeds should be covered properly with soil. In each hole 1–2 seeds are dibbled.

Intercultural operations

If two seeds were sown, leave only one healthy and vigorous seedling per hole and remove the other after 12–15 days of sowing. Where seedlings have not germinated, dibble presoaked seeds at the rate of 2 seeds per hole and immediately irrigate.

Apply 20 kg N 25 days after sowing, 20 kg N before detasseling and 20 kg N after detasseling of the crop.

First irrigation should be given immediately after sowing. Then the irrigation should be given at 7–10 days intervals without any break so that the soil moisture is always kept at normal state and the crop is not subjected to any moisture stress. About 50% of water requirement is within 30–35 days after tassel formation. But any water shortage at the grain filling stage will reduce its quality.

The first weeding should be done on 15th day of sowing. About 2–3 light hoeings and hand weedings are necessary to check the growth of weeds. There should not be any intercultivation after flowering.

Baby corn is an immature part of the female flower, removing the male flower (tassel) is essential to maintain the quality of baby corn. Remove the tassel of the plant as soon as it emerges from the flag leaf prior to pollen grains shedding in the plant to avoid pollination. On 40^{th} day detasseling is done (removal of male flowers before pollen shedding). This process is a must to avoid pollination and fertilization so that the hardening of the grains can be avoided to maintain the tenderness of the cob. If the pollination is allowed then the individual grain will become hard with the result the quality will get affected.

Pest and disease management

Apply bleaching powder to prevent the attack of mole cricket to optimize the plant population per hectare. A basal application of 10 kg/ha of carbofuran 3G is recommended to avoid all sucking pests or spray neem seed kernel extract 5% as a precautionary measure when the crop is 20–25 days old. Stem borer, pink borer and shoot fly are serious pests of corn. They can be controlled by spraying of carbaryl (0.2%) in the central whorl of plant.

Harvesting and yield

Small cobs are to be harvested at 3–5 days after their emergence without damaging the plant. Harvesting should be done when baby corn silk comes out 2–3cm from the top of ears. In special varieties meant for baby corn like VL Makka 42, Golden Baby and Early Composite, first cob will be ready for harvest at about 47–50 days after sowing. After 8–10 days of first harvest, second and third cobs will be ready for harvesting. The cobs are 8–10 cm long with golden yellow colour. Picking can be continued once in 2 days up to 65th day of sowing. A total number of 6–7 pickings can be done in a total crop duration of 65 days and about 5000- 6000 kg of tender baby cobs can be harvested from one hectare.

Select baby corn still in the husk to ensure it is still moist. Peel back the husk and look for small, full kernels in straight rows; the end should be tapered. Avoid baby corn whose kernels are sunken or wrinkled. Bright yellow baby corn will be sweet; white baby corn will be a bit starchier. Baby corn will keep in a loose plastic bag in the refrigerator for 2–3 days, but is best served fresh. Before serving or cooking, carefully remove the husk and silks so as not to break or damage the ear. Trim away the stem end. •

CHAPTER 23

Okra

OKRA is said to be a native of South Africa or Asia and has been predominantly a vegetable of the Tropics. It has found its place in India for more than a century. Okra is known by many local names in different parts of the World. For example it is called lady's finger in England, gumbo in USA, *bhindi* in India. Okra is commonly grown in almost all parts of the plains and is consumed by the common people in all the states. In India okra is grown in an area of 5,18,000 ha with a production of 62,59,000 tonne and a productivity of 12.1 tonnes/ha. The major okra producing states are, Uttar Pradesh, Bihar, Odisha, West Bengal, Andhra Pradesh, Karnataka and Asom (NHB, 2011).

Fig. 31. Okra

The green fruits of okra, are cooked and eaten, and the mucilage secreted in tissues of some species has been used in certain confections and for other purposes. Okra fruits are rich in calcium (90 mg/100 g fresh weight) and provide valuable supplementary items in the tropical diet, which is basically starchy in nature lacking calcium and iron. Tender, green fruits are cooked in curry and soup. High iodine content in fruits helps control goiter while leaves are used in inflammation and dysentery. The fruits also help in cases of renal colic, Ieucorrhoea (thick, whitish or yellowish vaginal discharge) and general weakness.

100 g edible portion of okra contains 88% water, 77% carbohydrates, 2.2% protein, 58 I.U vitamin A, 633.0 vitamin B, 16 mg vitamin C, 0.7% Ca and 1.2% mineral matter. The dry seed contains 13–22% good edible oil and 20–24% protein. The oil is used in soap, cosmetic industry and as vanaspati while protein is used for fortified feed preparations.

Botany

Okra [*Abelmoschus esculentus* (L.) Moench.; 2n = 130)] belongs to the family Malvaceae, or the mallow family, which is a family of flowering plants containing

over 200 genera with close to 2,300 species. Well known members of this family include okra, jute and cacao. Okra plant is an erect, herbaceous annual, 1–2 metre tall and forms fairly heavy tap root; bisexual flowers and erect vegetative growth with or without branches. The fruit is a capsule which may be light green, or sometimes red.

Floral biology and pollination: A flower bud appears in the axil of each leaf above 6th to 8th leaf depending upon the cultivar. Flowers solitary, axillary with about 2 cm long peduncle; epicalyx up to 10, narrow hairy bracteoles which fall before the fruit reaches maturity; calyx splits longitudinally as flower opens; petals 5, yellow with crimson spot on claw; 5–7 cm long; staminal column united to the base of petals with numerous stamens; ovary superior, stigma 5–7 mm, deep red. A flower bud takes about 22–26 days from initiation to full bloom. The time of anthesis varies with the cultivar, temperature and humidity and it ranges from 8–10 AM. The dehiscence of anther occurs 15–20 minutes after anthesis. The dehiscence is complete in 5–10 hours for fertilization after pollination. The flowers remain open for a short time and they wither late in the afternoon. The stigma is receptive at the time of opening of flowers. It is a cross pollinated crop.

Breeding

Earlier attempts were made to study the inheritance of various economic characters and up till now inheritance of almost all characters have been studied. Attempts were also made to achieve interspecific crosses to the best advantage of the useful characters especially the source of resistance to diseases and pests to be incorporated in the cultivated species. The variety 'Pusa Sawani' was evolved, which was highly tolerant to the yellow vein mosaic virus (YVMV) and later on it became susceptible. IIHR bred a variety Arka Anamika which is highly resistant to YVMV. Almost immune source to YVMV has been recorded in the wild species, *Abelmoschus manihot.* Interspecific relationship among different species of okra was studied. Efforts were also made to exploit hybrid vigour and as much as 60% increased yield was reported. Induction of male sterility by use of chemical was made possible to exploit commercial hybrid seeds production. Studies on heterosis for yield and yield components have been reported and F1 hybrids have been developed. Evaluation of okra lines for resistance to yellow vein mosaic virus in humid tropics revealed that *Abelmoshus ficulneus* L. Moench, *A. tetraphyllus, A. manihot* ssp. *tetraphyllus* and *Hibiscus huegelii* were resistant to the virus under the hot spot situations. Among the cultivated types, Arka Anamika and Parbhani Kranti were found to be tolerant up to the 15^{th} harvest. Yellow mosaic virus resistant F_1 hybrids in okra have been developrd (Nath *et al.* 2002).

In okra, commonly adopted breeding methods are hybridization, pedigree selection, backcrossing, recurrent selection and pure line selection. Induced mutation has been successfully utilized by PAU, Ludhiana, to develop an improved variety EMS–8 which is resistant to YVMV and tolerant to fruit borer. An induced mutant variety MDO-1 and Parbhani Kranti were released by TNAU, Madurai, and MAU, Parbhani, respectively (Swarup, 2006).

Improved cultivars

Virus resistant cultivars

Pusa A-4: Released from IARI, New Delhi. Plants with single stem, sparse pigmentation and short internodes. The fruits are 5- ridged, attractive dark green, 12--15 cm long having excellent shelf life. It is resistance to Yellow Vein Mosaic Virus and tolerant to aphids and jassids and least preferred by shoot and fruit-borer. Maturity 45 days (first harvest). Yield 6.74 tonne/ha.

Punjab Padmini: Developed by PAU, Ludhiana. Plants tall (180–200 cm), plant parts pigmented and hairy. Fruits dark green, 15–20 cm long, 5 ridges, remain tender for a long period (3–4 days). Resistant to yellow vein mosaic virus. Maturity 50–55 days. Yield 100–125 q/ha.

Parbhani Kranti: Plants single stemmed, tall, deeply lobed green leaves. Fruits smooth, dark green, tender, 5 ridged with long narrow tip. Resistant to yellow vein mosaic virus. Maturity 50 days. Yield 85–90 q/ha during summer and 100–115 q/ha during *kharif* season.

Punjab-7: Developed by PAU, Ludhiana. Plants medium tall (105 cm), partial pigmentation. Fruits medium long, green, tender, 5-ridged, slightly furrowed. Resistant to yellow vein mosaic virus. Maturity about 54 days. Yield 80–95 q/ha.

CO-1: Released from TNAU. Its plants are tall with 6–8 branches. The fruit starts from 5th node. The fruits are glossy, slender, 5-ridged, scarlet red (colour non persistent on cooking), borne on an average 20 fruits/plant. Maturity 50 days. Yield 85–90 q/ha. Cultivation year-round in Tamil Nadu. It has field tolerance to yellow vein mosaic virus (YVMV), but is susceptible to fruit borer and powdery mildew.

TN Hybrid-8: Released from TNAU. The plants are branched type having sparse pigmentation except on fruits, green foliage and green, 5 ridged, medium long fruits. It has fair degree of adaptation and is also a high yielder even under north Indian conditions. It is resistant to YVMV.

Arka Anamika: Developed by IIHR, Bengaluru. Plants open, 100 cm tall partial pigmentation. Fruits dark green, 5 ridged, furrowed. Excellent yielder in southern states. Resistant to YVMV. Maturity 55 days. Yield 120 q/ha. Developed by IIHR, Bengaluru.

Arka Abhay: Developed by IIHR, Bengaluru. Plants tall, well branched, fruits lush green, tender and long, fruits borne in clusters, green stem with purple shade. Fruits free from spines having 5–6 ridges and delicate aroma. Good keeping and cooking qualities Field tolerant to YVMV. Duration 120–130 days, yield 180 q/ha. Recommended for Karnataka, West Bengal and Asom.

Punjab-8: Developed by PAU, Ludhiana. Plants 150 cm tall, hairy partial pigmentation. Fruits medium long, green, tender, 5 ridged. Plants resistant to YVMV and tolerant to fruit borer. Maturity 50 days. Yield 105 q/ha. Variety developed by mutation at PAU, Ludhiana.

Hissar Unnat: Developed by HAU, Hisar. Plants are medium tall with 3–4 branches, green foliage. Fruits green, attractive, 5 ridged, 15–16 cm long. Resistant to YVMV. Maturity 55 days. Yield 120 q/ha.

Varsha Uphar: Developed by HAU, Hisar. Plants 90–120 cm tall, 2–3 branches,

and pigmented petioles. Fruits attractive dark green, 18–20 cm long, long tapering tip. Resistant to YVMV, field tolerant to borers. Maturity 45–50 days. Yield 100 q/ha.

Azad Kranti: Developed by CSAUAT, Kanpur. Plants fast growing, occasionally branched, sparse pigmentation. Fruits 5 ridged, smooth, shiny, green, long beak. Highly tolerant to YVMV. Maturity 50–55 days. Yield 125 q/ha.

Kashi Vibhuti: Developed by IIVR, Varanasi. Resistant to YVMV, okra leaf curl virus (OLCV). Yield 170–180 q/ha; a plant bears 18–22 fruits having 8–10 cm length.

Kashi Satdhari: Developed by IIVR, Varanasi. Resistant to YVMV, 18–15 fruits/plant and 110–140 q/ha. Recommended to Punjab, Bihar and Jharkhand.

Shitta Jyothi: *S*uitable for warm, humid climate. Yield 180–200 q/ha. Resistant to YVMV and OLCU. Recommended for Rajasthan, Gujarat, Haryana, Delhi, Chhattisgarh, Odisha and Andhra Pradesh.

Other cultivars

Pusa Sawani: Developed by IARI, New Delhi. Early, plants generally single stemmed, fruits 12–15 cm long, 5 edged, smooth and dark green when fully developed, suitable for spring summer cultivation. Less sensitive to temperature fluctuations but sensitive to virus. Maturity 50 days (first harvest). Yield 120 q/ha.

Pusa Makhmali: Developed by IARI, New Delhi. Excellent fruit quality, susceptible to virus, suitable for cultivation in hills and virus free areas and season. Plants hairy, erect, 180–200 cm tall. Fruits light green, tapered, attractive, 12–15 cm long. First harvest in 50–55 days. Yield 80–100 q/ha.

Kashi Pragathi: Developed by IIVR, Varanasi. Fruits 23–25/plants 8–10 long, yield 180–190 q/ha rainy season, 130–140 q/ha in summer season. Recommended to Chhattisgarh, Odisha and Andhra Pradesh.

Kashi Bhairav: Developed by IIVR, Varanasi. Fruit length 10–12 cm. Yield 200–220 q/ha. Suitable for all the states.

Kashi Mahima: Developed by IIVR, Varanasi. The length 12–14 cm yield 200–220 q/ha. Uttar Pradesh, Punjab, Bihar, Karnataka, Chhattisgarh, Odisha, Andhra Pradesh, Maharashtra.

Red Bhendi: Released for southern plains, its fruits are 5-ridged, red, long and slender, fleshy with lesso seeds than Pusa Sawani, It givc good yield under southern plai ts though its cultivation is limited,

Climate and soil

Being a warm season crop it is susceptible to cold and frost. It thrives well during warm, moist season although it grows fairly well in the hottest summer. The seeds do not germinate below 17°C. Okra flowers drop at 40–42°C day temperature. Uniform day and night temperature levels is preferred by okra, wide difference between day and night temperature reduces the seed yield considerably. Well drained sandy to clay soils supplied with enough organic matter are good for okra cultivation. However, loose, friable and well manured loam soils having the pH range between 6.0 to 6.8 are the best.

Cultural requirements

Sowing time: Okra can be grown throughout the year where frost and severe winters are absent. Sowing can be done in southern plains during June-July, September-October, and February-March; in northern and western plains during July-August and February-March; in eastern plains May-June, and February-March; and in hilly areas during April-June.

Land preparation and sowing: Prepare the land by ploughing and harrowing and incorporate 25 tonne/ha of farmyard manure to the soil. Prepare ridges and furrows at a spacing of 60 cm (for *kharif* crop) or 45 cm (for spring-summer crop). Sowing on ridges ensures proper germination, reduces water requirement during spring-summer and helps in drainage during rainy season. Open small furrows at the bottom of the ridges and apply 50 kg N, 50 kg P and 50 kg K/ha and cover with soil. Irrigate the furrows 2 days before sowing.

Seeds should be soaked in clean water for 24 hours before sowing. Seeds which will not absorb water during imbibition should be discarded. Seeds are sown in lines. Soaking seeds in carbendazim 50 WP (0.2%) solution overnight also helps activate germination and protects seedlings from wilt. Soil treatment with furadon @ 20 kg/ha helps protecting plants from root knot nematodes and other pests during initial 4–5 weeks. Sufficient soil moisture and temperature around 30°C help in quick and uniform germination. Sowing in moist soil is preferred. Give a light irrigation after sowing.

Okra requires about 15–20 kg/ha of seeds during spring-summer and 8–10 kg/ha for the rainy season. During spring-summer, the vegetative growth is relatively less and hence, a spacing 45 cm between rows and 15–20 cm between plants in a row may be given. During the rainy season where growth is vigorous, a spacing of 60 cm between rows and 30 cm between plants in a row may be given.

Intercultural operations

Depending on the soil moisture available the crop should be irrigated at frequent intervals. At the time of sowing, enough moisture should be available to help germination. For a continuous growth and pod formation, the crop should be irrigated every fifth or sixth day during hot season and every fortnight during cold season. Maintain the spacing between plants in the rows by thinning out the extra seedlings. Hoeing and weeding should be done at regular intervals depending upon the need. Care should be taken to drain the excess irrigation water or rain water, because it adversely affects the plant growth. Apply the remaining 50 kg N/ha as top dressing 30 days after sowing followed by earthing up operation.

Pest and diseases management

Diseases

Yellow vein mosaic virus: It is a very common virus disease and limits the cultivation of this crop in some seasons. When the disease appears very early, all the leaves become completely yellow, later on turn brown, dry up and shed. Such plants hardly bear flowers and the plant dies prematurely. If the infection takes place at the later stage, the earlier formed leaves on the main stem remain green,

whereas the top leaves and flowering part as also the secondary branches show clear symptoms. On such plants, although the fruits are formed in good number, they are uniformly yellow at the picking stage and as such are unmarketable. In the beginning, the few infested plants may be uprooted and destroyed. The alternate host plants near the bhindi plot should be removed. This can be controlled by spraying acephate (0.15%) followed by spraying of imidacloprid (0.033%) at 15 days interval and thus minimizing the vector (white fly, *Bemisia tabaci* Gen.) population. Resistant varieties like P-7, Hisar Unnat, Varsha Uphar, Azad Kranti, Arka Anamika, may be grown.

Powdery mildew (Erysiphe* sp.*): White grayish powdery coating is seen on the under surface of the leaves. Leaves which are severely affected turn yellow and drop. It may be controlled by spraying wettable sulphur (0.3%) or hexaconazole (0.075%) or dinocap (0.1%) at 10 - 15 day intervals from the onset of powdery mildew.

The other diseases are Cercospora leaf spot, Fusarium wilt and Alternaria blight diseases. Spraying of wettable sulphur (0.3%) or hexaconazole (0.075%) or dinocap (0.1%) at 10 - 15 day intervals, the Cercospora leaf spot disease can be controlled. If Fusarium wilt is observed, drench the soil with carbendazim (0.2%). Foliar application of mancozeb (0.25%) or chlorothalonil (0.25%) will control the Alternaria blight.

Insect pests

Hoppers: In the initial stages of crop (before flowering) spray systemic insecticide like thioethoxam 0.3 g/l, or imidacloprid (0.3 ml/L) for managing hoppers. Once the fruit harvest starts, avoid spraying insecticides

Shoot and fruit borer: Spray neem or pongamia soaps @ 0.5% or pulverized neem seed powder extract (NSPE) 4%. Give the lower surface of the leaves thorough spray, as the pest is generally found there. Collect and destroy the affected fruits and stems.

Aphids: Clipp and destroy aphid infested shoots and plant parts. Spray a systemic insecticide like dimethoate 30 EC (2 ml/litre) for controlling aphids.

Mites: Spray dicofol 18.5 EC @ 2.5 m1/litre or any other acaricide like wettable sulphur 50 WP 3 g/litre to control mites. Thorough spray on the under surface of the leaves is to be ensured for getting good control.

Harvesting and yield

Okra production begins early and plant continues to flower and fruit for an indefinite time, depending on the variety, the season, and soil moisture and fertility. Normally, flowering begins from 35–40 days after sowing of seed. Flowers remain open for only 1 day, and the pods develop rapidly thereafter. The young fruit can be harvested at any stage until the fibre content becomes excessive. As a general rule, fruits are ready for harvest 4–10 days after flowering. Because of the rapid growth of okra fruits, plants should be harvested at least every other day. In climates where growth is especially vigorous, it may be necessary to harvest every day. Regular harvesting stimulates continued fruiting. When pods are not removed, the plants age rapidly. Signs of aging are a reduction in the production of leaves

and an increase in the depth of lobing. The evening is the best time for harvest, for the highest quality fruits are obtained then.

The crop is ready for first picking 50–55 after sowing. Harvest the tender fruits in 2–3 days interval depending upon the season. The fruit picking may continue up to 70–75 days after flowering. Early harvesting gives lower yields of tender fruits with shorter shelf life. In general harvesting on every alternate day is advisable. A cheap hand glove or cloth bag should be used to protect fingers. All large pods are removed at harvest by means of a sharp knife or pruning shears; with some varieties the fruit can be snapped off. The fruits are immediately removed from the sun, for their quality decreases rapidly after harvest. Harvesting in the morning is convenient for distant markets; harvesting during late evening and transporting during night is also advised. Depending upon the variety and stage of harvest of fruits, the fruits yield ranges from 150–200 q/ha.

Seed production

No special agronomical practices need to be followed for the crop raised for seed production. Land should be kept clean by weeding and mulching. Irrigation is to be provided during dry season as and when required. In wet season, however, irrigation should only be given if there is no rain for a longer period. Earthing up along the lines is done at the time of top dressing with 50 kg N/ha.

Okra plants are self pollinated but a considerable extent of cross pollination has been recorded (about 20%). A minimum isolation distance of 500 m is desirable between two varieties for producing pure seeds.

Roguing is very important and should start as early as possible. All of types of plants affected by virus must be removed as soon as they are observed. The crop will normally require several roguings. Plants are inspected for various morphological characteristics during flowering and fruiting stages and the off type plants are removed.

Flowering starts 35–60 days after sowing. About 5 weeks are required from flowering to the production of dried pods with fully viable seeds. Fruits turn from green to gray or brown and become hard on ripening. Seeds obtained from basal pods are heavier and of good quality. Pods of okra are angular in shape and have the tendency to open along sutures when dry. This will cause shattering loss and the seeds may be damaged due to entry of rain water inside if there is rain. Pods, therefore, must be harvested as soon as they have become mature and before shattering. Pods are best harvested by hand individually and thereafter dried.

Threshing of seeds is also done by hand after the pods are sufficiently dry. Light seeds are then removed by cleaning and winnowing. Collected seeds are sun dried to moisture level not exceeding 12% for open storage and up to 9% for sealed container storage. The seed yield ranges from 1000–1500 kg/ha. ●

CHAPTER 24

Perennial vegetables

PERENNIAL vegetables are those which produce the edible portion continuously for several years. They occupy the land for a number of years and therefore should be located where they will not interfere with normal tillage operations for other crops. When grown in the home garden, they should be planted on one side of the main plots for growing annuals. The vegetables which are grouped as perennials are asparagus, drumstick, curry leaf, breadfruit, artichoke, and Jerusalem artichoke. These crops have tuberous roots, rhizomes or crowns. The upper portion may dry up during very cold winter months and again sprout with the coming of spring.

ASPARAGUS

It has probably originated in European region. Asparagus, (*Asparagus officinalis*), comes from the Greek word *asparagos*, which first appears in English print around 1000 AD. It cannot be definitively tracked to any one specific area of origin, although it is known to be native to the eastern Mediterranean and Asia Minor areas. As early as 200 BC, the ancient Egyptians cultivated it. The Romans cultivated the plant in 200 BC. It has, over the centuries, been taken into gardens from the wild and progressively improved by selection. It was perhaps introduced to India during the early British period.

In China, there are several wild species; the tuberous roots of some of which are used as food as well as in medicine. Asparagus is now an important crop, especially in Taiwan where the shoots are canned for export. It is widely grown in East Africa and Malayasia. The Asparagus is cultivated mostly for its tender shoots, commonly known as spears. This vegetable is of great importance in the diet because of its valuable salts, vitamins and for its large amount of cellulose contents. The Asparagus is a perennial plant, with underground fleshy root stock. The young shoots are eaten when 6–15 cm high.

In Hindi it is known as *shatawar.* It is a cool season crop which thrives over a wide range of temperature and fairly tolerant to frost. It is a perennial plant giving yield 2–3 years after planting and can be left in the field for 10–15 years. The asparagus is cultivated for its tender shoots, commonly known as spears. The spears are treated as a delicacy in preparation of soup and other vegetable products. Large quantities of asparagus spears are canned and frozen. The soft tender shoots called ‘spears’ are used as salad/vegetable in soup. The roots are numerous and

fleshy and they occur horizontally inside the soil and serve as storage organs. The crown is made up of roots and rhizomes. The spear (aerial stem) arises from a bud on the rhizome. The tender shoots contain a chemical 'asparagine' which is used in the medicine as diuretic.

Botany

Asperagus (*Asparagus officinalis* Linn.) belongs to the family Liliaceae/Asparagaceae. Asparagus shoots arise from underground rhizomes (a type of stem) early in the spring. Because the plant is a perennial, asparagus is one of the first fresh vegetables on the market. Asparagus is an important perennial vegetable crop, both commercially and in home gardens. It is a monocot of the family Asparagaceae. The underground portion consists of stems or rhizomes, and the edible aerial stems grow upward from them. Young "crowns" consisting of roots and rhizomes are grown from seed planted in beds and transplanted to the field. Fields with good care will produce for years. The tender, succulent aerial stems are cut for 2–3 months as they emerge in spring. Then cutting stops and they are allowed to grow to nourish the underground part for the following year's crop. Cutting may be deep in the soil with just the tip emerging for "white" or near the soil surface when spears are 6 to 8 inches high for "green" asparagus. Spears consist essentially of stem tissue only. Asparagus plants are hardy herbaceous, dioecious and perennial. The spears are the edible stems or unexpanded shoots arising from the buds developed on the old rhizomes. The spears will elongate if not harvested and produce secondary and side branches with small leaf-like feathery structures (cladophylls). In asparagus male plants are higher yielding than the female plants. The chromosome number of *Asparagus officinalis* is 2n=20.

Breeding

Asaparagus in cross pollinating because the plants are dioecious. The plants raised from seeds are heterogeneous. The asparagus varieties grown in India are exclusively exotics from the USA, Europe or Australia. The old popular varieties are Mary Washington, Marth Washington, New Jersey Improved, Waltham Washington, Viking, *etc.* and most of them are selections from Mary Washington. An exotic variety "Perfection" has been recommended by IARI, New Delhi. It is early with large green succulent spears, uniform maturity and high productivity.

Cultivars

Marth Washington, Mary Washington, New Jersey Improved Perfection, are some of the important varieties of asparagus. Since the plants are dioecious (*viz.*, male and female plants are separate), cross pollination is the rule and on any account no two varieties shall be grown side by side to maintain the identity of the cultivar. The varieties are broadly divided into two groups, one with spears overcast with purple and the other with spear tips almost free from the purple overcast. The variety 'Perfection' is recommended by IARI, New Delhi.

Climate and soil

Asparagus is a cool season crop. It performs better in the hills than in the

plains. Its optimum temperature for growing is 16 - 24°C. The ideal day temperature is 25–30°C and night temperature 15–20°C. It can slightly tolerate frost. It grows well on fertile and well drained loam soil. The optimum soil pH is 6.5–7.5 for its good plant growth. It has high tolerance to salinity and slightly tolerant to acidic and alkaline soils.

Cultural requirements

Sowing time: Seed sowing or planting can be done during July-November in the plains and in March-May in the hills.

Nursery raising: Aspragus is grown by seeds or crowns. The seeds are sown in a well prepared nursery bed in rows 50 cm apart. Seeds are sown in nursery beds but before sowing these are soaked in water for about 3–4 days. The optiumum temperature for seed germination is 25–30°C. The seedlings are allowed to grow for one year in the nursery bed and are then planted at the permanent site. The seed is sown in early spring and it takes 3–4 weeks to germinate.

Asparagus plants are dioecious in character that is, the male and female plants are separate. The male plants bear more spears than the female plants. It is not possible to recognise the sex of the plants in the nursery as most of the plants will not flower within one year. The age of transplant is one year seedling or crown. Therefore, selection is usually made on the basis of root growth. Those crowns which have a good growth and branching should be selected. Older crowns may have more roots but a number of them may have already been mutilated. The crowns are dug up from the nursery at depths of about 20 cm. About 15,000–25,000 plants/ha are required to use crowns from one year old plants for propagation of asparagus.

Land preparation and planting: Proper preparation of soil is essential as the crop occupies the soil for a number of years. A good amount of organic manure should be incorporated at the time of preparation of the soil. The rows are spaced at about 1.5–2 m and 45–60 cm distance is kept between plants within the rows. It is necessary to add about 50 kg N, 25 kg P and 50 kg K/ha every year. The best way of applying fertilizers is to apply them in two doses. The first dose may be given in early spring before the start of growth and then again after the harvest is complete.

Seedlings 10–12 weeks old are transplanted in the field. Planting can be done in double rows also but at slightly wider spacings. Seeds are also sown directly at the bottom of 15–20 cm deep furrow and covered with 3–5 cm of soil. Later when the seedlings develop, soil is gradually filled to cover them. This method of seed sowing is practiced for production of white or blanched spears.

Intercultural operations

When the rows are far apart, the interspace can be utilized for the first 2–3 years by growing some intercrops. Every year it is desirable to disk and harrow thoroughly and apply fertilizers before the growth starts.

The first irrigation is given at the time of planting and thereafter at 10–15 day intervals. The water is allowed to stand in furrows to facilitate percolation. Excessive irrigation should be avoided and proper drainage should be provided.

Under temperate conditions, the crows become dormant during winter and formation of spears starts in the beginning of spring. In mild climatic conditions, the dormancy is not distinct.

Weeds between the rows can be kept under control by shallow hoeing so that the young sprouts are not damaged. Weeds should be removed as and when required.

Mounding the soil to a height of 25–30 cm over the rows is practiced to blanch the young spears and get 'white asparagus' for canning. After harvesting the green asparagus sent for fresh market, blanching is normally done to produce white asparagus.

Pest and disease management

Asparagus rust is the most serious disease. The tops of the plants are destroyed when severely attacked. There are some varieties which are resistant to rust. In places where the disease is prevalent, it is advisable to grow such varieties. Asparagus rust disease can be controlled, by dusting 25–30 kg/ha of sulphur after cutting season.

The other disease which is not so common as rust is *Fusarium* wilt. Spears affected with wilt may show a brown discolouration and become wilted and stunted. There is no direct control measure as the disease organism is soil borne. It is best to avoid the neighbourhood of such soils which show wilt for planting asparagus.

Asparagus beetles and garden centipedes are the only insect pests which attack asparagus.

To control asparagus beetle, spray the crop with carbaryl (0.2%). To control garden centipede which cuts the sprouting spears, the field should be flooded.

Harvesting and yield

The first harvesting of spears is two years after planting or seed sowing. After harvesting, every year about 20–30 kg N/ha should be applied for better plant growth. It starts yielding a sizeable crop after about three years and with good care gives an economic yield for about 10–15 years. The yield goes on increasing for 6–7 years, then remains uniform up to about 12 years, after which it gradually declines. The best quality is obtained from the fourth to the tenth year.

Sometimes blanched (whitish) spears are preferred particularly for canning. The green spears being higher in nutritive value are preferred now for the fresh market or for processing. Harvesting is done from the third year onwards. In the second year some spears may be available. It is harvested every day during spring. Spears may be cut by a special knife which cuts 3–5 cm below the soil surface. Asparagus loses quality quickly after harvest. So it should be sent to the market as soon as possible. The average yield per hectare every year is about 3,500–4,000 kg.

The aerial shoots called "spears" arise from the buds on the rhizome six months after planting of crowns or seedlings. The spears should not be harvested up to one year after planting the crown, because of active growth of root system and rhizome during this period. The production of spears is at the expense of food

stored in the roots during the previous year and as such, sufficient time should be allowed for storage of food material. The first cutting should be restricted to a limited period of 2–3 weeks in the first cutting and 8–12 weeks in the subsequent years of regular harvesting. Well grown spears are cut with a knife called 'asparagus knife', which has a wide chisel-like blade. By holding the tips of the spears in the left hand, the knife is pushed down at an angle of 45°C to the spear to cut it off below the ground surface. The height below the ground surface should be more when white asparagus is produced and vice-versa for green asparagus. Care should be taken while cutting, so that the young adjacent sprouts are not damaged. Crooked and curved spears are rejected. After harvest, they are made into bunches and carried to sheds, where grading trimming, washing and packing in crates are done. After packing, they are sent to the markets.

DRUMSTICK

Fig. 32. Drumstick

The Hindustan centre of crop origin is the cradle of many economically important vegetable crops. One of the vitamin rich mineral packed and nutritious vegetable of this tropical and sub tropical centre of crop origin, originally grown by Dravidians and later by Aryans in each and every home yard. Though the origin of drumsticks is India, due to its medicinal uses it has reached other countries also. Different varieties and types of drumsticks are found in specific part of India. The tree is indigenous to North-West India. It is found growing wildly in the sub-Himalayan tract from river "Chinab" eastwards to "Sarda" and in the *Tarai* tract of Uttar Pradesh in India. Streches of the wild form of the tree can be seen at the *Tarai* belts of Uttar Pradesh and Bihar. The tree is widely distributed in India, Egypt, Philippines, Ceylon, Thailand, Malaysia, Burma, Pakistan, Singapore, West Indies, Cuba, Jamaica and Nigeria.

English common names include moringa, and drumstick tree, horseradish tree, West Indian ben, ben oil tree and never die. In Hindi it is known as *sejanki phali/ saijan.*The name drumstick derived from the shape of pod (long, slender, triangular seed pods) resembling the slender and curved stick used by drummers for beating the drum. Probably the name "horse radish tree" was derived from the from the taste/flavor of its roots which resembles horseradish. The name ben oil tree was derived from the ben oil extracted from drumstick seeds.

Moringa is one of the world's most nutritious crops. It is a commonly eaten vegetable in south Asian countries like India and Pakistan. Nutritionally, drumstick pods and leaves carry great nutritive value as they are a great sources of carotene, phosphorus, calcium and vitamin C. They are eaten for the treatment of ascites, rheumatism and venomous bites as an antiseptic and also as a cardiac and circulatory stimulants. Inhaling the steam of water in which drumstick has been boiled helps to give relief for asthma and other various lung problems. Drumstick

soup helps to ease any kind of chest congestions, coughs and sore throats. Liberal consumption of drumstick leaves helps to cure mouth ulcers and canker sores.

Drumstick leaves have seven times more vitamin C than oranges to fight against many illnesses including cold and flu; and the leaves have four times more vitamin A than in carrots to protect against eye diseases, skin diseases, and heart diseases; they have four times more calcium than that present in milk to build strong bones and teeth. It is three times more richer in potassium than bananas, which is essential for the functioning of the brain and nerves. It has twice the amount of the protein than in milk and almost equal amounts of protein present in eggs.

Drumstick is one of the most popular tree vegetables in Indian households. It is cultivated in home gardens and fields for its leaves, flower buds and tender fruits, all of which are used as nutritious vegetables. It is highly valued for the distinct and appealing flavour of its tender fruits. They are a rich source of protein, minerals and vitamins.

Seed is said to be eaten as peanut in Malaysia. Seeds contain an oil. Moringa oil is pressed from the seeds of the moringa tree and is non-drying. It is known commercially as ‘ben’ or ‘behen’ oil, which has been much used for illumination, soap industry and highly priced for lubricating watches, computers and other delicate machinery etc. Seeds contain 38–40% of a non-drying oil which is clear and odourless, never becoming rancid. It is edible and useful in the manufacture of perfumes and hair dressings. The press cake remaining after oil extraction is high in saponin, not edible, but utilized as manure. The oil cake is a water coagulant and used for purifying effluent water from rivers, ponds and shallow wells and it is used as organic substitute for water purifying chemicals such as aluminium sulphate (alum). Wood yields blue dye and yields a coarse fibre.

In developing countries, moringa has potential to improve nutrition, boost food security, foster rural development, and support sustainable land care. It may be used as forage for livestock, a micronutrient liquid, a natural anthelmintic and possible adjuvant.

This tree is becoming a vital source of nutrition in South Asian region, where most of the world’s poor people live. The multiple uses of moringa have attracted the attention of researchers, development workers, and farmers. It is one of the world’s most useful plants. This fast-growing tree is grown throughout the tropics for human food, livestock forage, medicine, dye and water purification.

Botany

Drumstick (*Moringa oleifera* Lam.; Syn: *M.pterygosperma* Gaertn.) belongs to the family Moringaceae, the genus *Moringa* and the species *oleifera*. The Moringaceae is a single genus family (monogeneric) with 14 known species. Of these, *M. oleifera* Lam (Syn: *M.pterygosperma* Gaertn.) is the most widely grown and utilized species.

It is a perennial tree with a fragile stem and grows to a height of even more than ten metres. Recently, a few annual types have been developed which are high yielding and respond well to ratooning. Drumstick is a deciduous tree of 8–10 m height. It is a small or medium sized tree with corky bark and woody and brittle stem. The roots are long and pungent. The leaves are feathery, tripinnate,

30–60 cm long, with slender rachis thickened and auriculated at base. The pinnae and pinnulae are opposite, 5–10 pairs with trifoliate upper most pair and with hairy gland between each pair of pinnae and pinnulae. The ultimate leaflets are opposite, 6–9 pairs, elliptic-ovate or obovate, pale beneath, entire with obscure membranous nerves. The other species available is *M.concanensis*. The tree is reported to be a true diploid with 2n=28 (Peter, 1998)

The tree itself is rather slender, with drooping branches that grow to approximately 10 m in height. In cultivation, it is often cut back annually to 1–2 meters and allowed to regrow so the pods and leaves remain within arm's reach.

Improved cultivars

KM-1: This variety was developed at Annia Farm, Kudumianmalai of Pudukkottai District in Tamil Nadu. It is a selection from an annual type propagated by seeds. The plant do not grow very tall and harvest of fruit becomes easier. Pods are short (32–37 cm) and thick (5.5–6.0 cm). The pod weight ranges from 65–82 g. The number of pods is 10–13. The plants come to bearing 6 months after planting. After each harvest, the plants can be rationed for 2–3 years but cutting the trunk at a height of one metre. Fresh planting of seedlings can be taken after three years.

PKM- 1: PKM- 1 is an annual type of murungai, evolved at Horticultural College and Research Institute, Periyakulam of Tamil Nadu Agricultural University. The plants grow to a height of 4–6 meters and come to flowering in 100–125 days after planting. Each tree bears on an average of 200–250 pods/ year. The pods are 60–75 cm long with 6.0 cm girth and 150 g weight. They are very pulpy containing 70% of edible portion. Every year after the harvest is completed, the trees have to be cut back to about one meter from ground level during September and three ratoon crops can be taken in a period of three years.

PKM- 2: This variety was released during January 2000 from HC and RI, Periyakulam of Tamil Nadu Agricultural University. It is a hybrid derivative of the cross between MP 31 and MP 28 of the types maintained in the germplasm. The plants are quick growing reaching a height of 4.8 m in six months. Each tree has 12 branches and bears flowers in clusters. Three to four pods are obtained per cluster. Plant starts flowering in 100–110 days and pods can be harvested in 170–180 days. Each pod weighs 280 g with a length of 125 cm and girth of 8.0 cm. Seed content is less with more flesh. Each tree yields on average 220 pods weighing 62 kg with an hectare yield of 98 tonnes.

Dhanraj (Sel 6/4): This is a variety developed by University of Agricultural Sciences, Dharwad. Starts yielding after 9–10 months of sowing/planting two year old tree yield 250–300 pods (fruits) per year fruits are 35–40 cm long. Since it is a short variety it is recommended as an intercrop in coconut and mango orchards and also as a sole crop in watershed areas. It is most suitable for homestead gardens.

GKVK-1: This is a variety developed by University of Agricultural Sciences, Bengaluru. Plants are short, grow to a height of 1.5 m. Yields 250–300 pods (fruits) each fruit weighing 40 g with 35–40 cm length. Most suited for high density planting.

GKVK-2: Developed by University of Agricultural Sciences, Bengaluru. Plants are dwarf and yield 300–400 pods/year.

GKVK-3: Developed by University of Agricultural Sciences, Bengaluru. Plants are dwarf and grow to a height of 1 to 1.5 m. Pods are long conical shaped and dark green in colour yields 250–300 pods per year most suited for high density planting.

DWD-1: It is developed by University of Agricultural Sciences, Dharwad. It is a clone obtained from root suckers having dark green highly aromatic shining leaves. It is sensitive to low temperature in winter season and hence the bud burst is poor during winter. The leaves have an oil content of 5.22%. It can be dehydrated at 50°C without loss of quality and made into dry powder.

DWD-2: It is developed by University of Agricultural Sciences, Dharwad. It is an open pollinated seed progeny with slightly pale green leaves having lesser aroma (4.09%). It is not very sensitive to low winter temperature.

Important local cultivars

Jaffna: It is popular drumstick type in South India and said to be introduced from Jaffna. It is highly suited for coastal tracts of Tamil Nadu, Kerala and Karnataka. This type bears long pods (60–90 cm in length) and with a soft flesh of good taste. This type of moringa can yield 400 pods per tree per year from the second year of planting which increases to 600 pods from the third year of planting.

Moolanoor murangai: It is a local commercially grown in Moolanoor of Erode district of Tamil Nadu The fruits are 30–35 cm in length with very soft flesh. One tree yields about 500–600 fruits per year.

Chavakacheri murungai: It is reported to have been introduced from a place called Chavakacheri near Jaffna. It is an ecotype of Jaffan moringa, which bears pods as long as 90–120 cm. Due to long size of pods, this type of moringa is highly damaged during transportation and is grown mostly in home gardens. It yields 500–600 pods per tree per year.

Chemmurungai: It is another ecotype of Jaffna moringa. It is said to flower and fruit throughout the year and also yields heavy crops of 400–500 fruits per tree per year. The tip of the pod is red in colour.

Palmurungai: It is also another ecotype of Jaffna moringa. It is preferred for its thicker pulp and better taste of the pods. It yields 400–500 pods per tree per year.

Punamurungai: It is another ecotype grown in the home gardens of Tirunelveli and Kanyakumari districts in Tamil Nadu. It yields 300–400 pods per tree per year.

Kodikal murungai: This is cultivated predominantly in the betelvine gardens of Trichirapalli, Tirunelveli, Tanjavur and Dharmapuri districts of Tamil Nadu. It is an annual type of moringa. The seeds of this variety are sown in the betelvine field just three months before planting of betelvine cuttings. The betelvine cuttings are planted near the moringa. This moringa tree is highly useful for training of betelvine and also gives shade. The pods of this type are shorter (20–25 cm in length) and thick fleshed. The pods and leaves are very tastier. The trees are short statured and the leaves are smaller. This is a distinct type propagated by seeds.

Kattu murungai: This type moringa are seen in Chidambaram areas in South Arcot district of Tamil Nadu. This is a wild type producing small and inferior quality pods. The trees are larger and leaves are bigger. The pods are 30–60 cm in length and fleshy but used as cattle feed.

Palamedu murungai: It is cultivated in Madurai district in Tamil Nadu. The pods are long (60–75 cm) having good taste.

Climate and soil

It is a tropical plant and grows well in the plains. However, it is found growing in the subtropical climate also. It is predominantly a crop of dry and arid tract where it has been found to perform well with higher yields. The optimum temperature for better growth is 25–35°C. It is highly susceptible to frost and high temperature exceeding 40°C causes flower shedding. Drumstick is not very exacting in soil requirements. It grows well in almost all types of soils except stiff clays. However, sandy loam soils containing lime is best suited for its cultivation. The crop is more or less confined to sandy soils as seen in the coastal areas.

Cultural requirements

The seed sowing is done in June-July and November-December in southern India. Sowing can be done in June-July in most parts of northern region.

The drumstick is propagated by both seeds and stem cuttings. The perennial types are propagated by one-year old long stem cuttings (90–100 cm length and 5–8 cm diameter). The annual types are grown from seeds.

The seeds are sown in pits that are 45 cm (length) × 45 cm (width) × 45 cm (depth) and spaced 2.5 m × 2.5 m. In each pit 10–15 kg FYM is applied before sowing. Two seeds are sown, about 3 cm deep, in each pit. About 500–600 g of seeds are required for sowing in one hectare.

The stem cuttings of the perennial types are also planted in pits of 1 m × 1 m × 1 m size, spaced at 3–6 m apart.

The seeds can be either sown *in situ* in the prepared pits or can be transplanted after raising the seedlings in polybags. The polybags may be of the size of 15 cm length and 7 cm width. The seedlings will be ready for planting in one month after sowing. An additional number of 75–100 plants are to be raised in polybags separately for gap filling one month after planting.

Intercultural operations

Three months after sowing, each plant is to be supplied with 100 g urea, 100 g superphosphate and 50 g muriate of potash and irrigated copiously. The plants are to be provided with 100 g of urea alone, three months after first application. For ratoon crops the above schedule with 25 kg of farmyard manure is recommended.

When the seedlings reach 75 cm height, the shoot tips are to be nipped to encourage side branches. The plants which are exposed to heavy winds, slender branches are liable to be damaged and break easily at the joints especially when fully loaded with fruits. In such situations, mounds are to be formed around the tree trunks up to a height of 30–45 cm from the ground level.

In the young plantation, intercrops like cowpea or okra or groundnut can be cultivated till the moringa plants become dense and cover the interspace.

Generally drumstick does not require much irrigation and it is a drought-tolerant crop. Irrigation is given in the pits before sowing and on the third day after sowing. Care should be taken to avoid moisture stress till the germination. Later on, irrigation is done once in 10–15 days according to the soil types. There should not be any water stagnation. There will be flower drop when the soil is too dry or too wet. Hence optimum moisture should be maintained.

Pest and disease management

Diseases

Moringa is resistant to most pests and diseases, but outbreaks may occur under certain conditions. For example, diplodia root rot may appear in waterlogged soils, causing severe wilting and death of plants. Drenching the soil around the plant with copper oxychloride (2 g/l) will prevent wilting of plants.

Insect pests

Bud worm: Bud worm (*Noorda moringae*) larva bores into flower buds and causes shedding. In order to manage this pest, plough around trees to expose and kill pupae; collect and destroy damaged buds along with caterpillar; spray insecticides like carbaryl 50 WP@ 1 g/l or malathion 50 EC @ 2 ml/l or monocrotophos @ 1.5 ml/l of water.

Leaf caterpillar: Leaf caterpillar (*Noorda blitealis*) larva feeds on the leaflets reducing them into papery structures. In order to manage this pest, plough around trees to expose and kill pupae; collect and destroy damaged buds along with caterpillar; spray insecticides like carbaryl 50 WP@ 1 g/l or malathion 50 EC @ 2 ml/l or monocrotophos @ 1.5 ml/l of water.

Hairy caterpillar: Hairy caterpillar (*Eupterote mollifera*) larvae seen in groups in tree trunks, feed gregariously, scraping the bark and gnawing foliage. Severe infestation leads to defoliation of the tree. In order to manage this pest, collect and destroy egg masses and caterpillars; Spray carbaryl 50 WP @ 2 g/l or Duspan @ 3 ml/l of water.

Pod fly/fruit fly: Pod fly/fruit fly (*Gitona distigma*: generally attack the developing fruits. The symptoms of damage are, drying and splitting of fruits from tip and oozing of gummy exudate from fruit. In order to manage this pest, collect and destroy all the fallen and damaged fruits; rake up the soil under the trees or plough the infested field to destroy pupa; spray insecticides like nimbecidine @ 3 ml/l of water during 50% fruit set and 35 days later. However spraying should be avoided two weeks before harvest of the fruits.

Bark caterpillar: Bark caterpillar (*Indarbela tetraonis*) larvae makes zig-zag galleries and these galleries are filled with silken webbed masses comprising of chewed material and excreta of larvae. In order to manage this pest, clean all webbed material and excreta; plug the holes with cotton wool soaked in fumigants like chloroform, formalin or petrol and seal it with mud.

Mites: Mite populations can increase during dry and cool weather. These pests

create yellowing of leaves, but plants usually recover during warm weather.

Other insect pests include termites, aphids, leaf miners, white flies, and caterpillars. Chemical control of insect pests should be used only when severe infestations occur. Choose a pesticide that targets the specific pest causing the damage, and avoid pesticides that kill or inhibit the development of beneficial organisms. Choose pesticides that last only a few days. Cattle, sheep, pigs, and goats will eat moringa seedlings, pods and leaves. Protect moringa seedlings from livestock by installing fence or by planting a hedge around the plot.

Harvesting and yield

The annual drumstick types come to harvest six month after sowing while the perennials types propagated by limb cuttings take 8–9 months for the bearing. Fruits of sufficient edible maturity are harvested. The fruits are ready for harvest 60 days after flowering. The period of harvest extends 2–3 months and each tree bears 200–250 fruits in annual types. In perennial types, the yield will be generally low (80–90 fruits/tree/year) in the first two years of bearing. Then it increases to about 500–600 fruits/tree/year in the fourth and fifth year and the pods are harvested mainly in March-June. A second crop can be harvested in September-October. The ratoon crops can be taken and the plants will develop new shoots and will start bearing after six months. At each and every ratoon the plants are to be supplied with manures and fertilizers

CURRY LEAF

Fig. 33. Curry leaf

Curry leaf tree is a tropical to subtropical tree native to Southeast Asia- India, Sri Lanka, Bangladesh and the Andaman Islands. Later spread by Indian migrants, it now grows in other areas of the world where Indian immigrants have settled. It grows wild in the Himalayas. Originated in the *Tarai* tract of Uttar Pradesh, it grows up to an elevation of 1,500 m and is widely distributed in India, Burma, Ceylon, China, Pakistan, Australia and Pacific islands. Curry leaf is a self-pollinated crop and variability is much limited.

Two related species of *Murraya koenigii* are *M. paniculate* indigenous to Burma and *M. exotica* an ornamental shrub indigenous to India, Ceylon and Burma. Curry leaf is found to grow wild along the foot hills and plains of Himalayas from Kumaon to Sikkim. Curry leaf is grown on large scale in Bengal, Assam, Deccan plateau, Western Ghats, Tamil Nadu, Karnataka and Kerala. In addition, it is a crop of every homestead. It is cultivated in Coimbatore, Salem and Trichirapalli districts of Tamil Nadu on a commercial scale.

Its leaves are used in many dishes in India and neighbouring countries. Often

used in curries, the leaves generally go by the name "curry leaves", though they are also translated as "sweet neem leaves" in most Indian languages (as opposed to ordinary neem leaves which are bitter). In Hindi it is known as C*urry patta/ Kari patta/Meetha neem* and in Kannada as *karibevu.*

Curry tree is much cultivated for its aromatic leaves. The leaf is used in South India as a natural flavouring agent in various curries. Volatile oil is used as a fixative for soap perfume. The leaves, bark and root of the plant are used in the indigenous medicine as a tonic, stimulant, carminative and stomachic. Leaves are also used in pickles and chutney.

It is most common in every household in southern states, viz. Tamil Nadu, Karnataka, Kerala and Andhra Pradesh. It is also popular in Maharashtra, West Bengal, Assam and Deccan Plateau. It is cultivated on commercial scale in Tamil Nadu, Karnataka and Andhra Pradesh.

Its leaves are used for flavouring curries, *sambhar, rasam* and vegetable preparations. Since the leaves are widely used for food flavouring in curry preparation, hence the name curry leaf. Curry leaf is used in many Ayurvedic and Unani prescriptions.

As it contains vitamin A, iron and calcium, its leaves, roots and bark are credited with tonic, stomachic and carminative properties. Leaves are reported to cure piles and allay heat of body. The green leaves are said to be eaten raw for treatment of dysentery. External application of pulped bark and root is reported to relieve eruptions and bites of poisonous animals. An infusion of toasted leaves is used to stop vomiting. The tribal people of India use its ground bark for a drink and they rub the bark on the bitten limp as a snake bite remedy. The powdered leaf is used to aid in healing of fresh cuts and decoction of the leaves is drunk for dropsy.

The dried curry leaf powder is a good spice powder for use in the food stuff preparation. It is also being exported. Fresh leaves on a steam distillation under high pressure (41 kg/6.25 m^2) yield 2.6% volatile oil which is used as fixative for heavy type of soap and perfume. Rectified leaf oil is deep-yellow in colour with a strong spicy odour and pungent clove like taste. A volatile oil, a crystalline glucoside ksenigin from the leaves and murayin from the flowers are industrial products.

Botany

Curry leaf [*Murraya koenigii* (L.) Spreng.] belongs to the family Rutacece, the genus *Murraya*, and the species *koenigii.* The curry leaf tree is a large shrub or small tree. The leaves are used as is a spice. The tree is an aromatic deciduous one, 5 m in height, 15–40 cm in diameter. It is cultivated mainly in homesteads but to a certain extent on a plantation scale. Its stem is slender and strong. The branches are covered with dark-grey bark. The leaves are imparipinnate, leaflets 9–25 ovate, lanceolate, almost glabrous above and pubescent below. The leaves are gland dotted and strongly aromatic. Flowers are terminal corymbose cymes. The berries are subglobose or ellipsoid, purplish black when ripe and two seeded. The roots are woody, widely spread and produce many suckers. The tree bears flower from February-May. The curry leaf tree is a true diploid with 2n=18 (Peter, 1998).

Breeding

At the Department of Horticulture, University of Agricultural Sciences, Dharwad, two genetically distinct cultivars, *viz.,* DWD 1 (Suvasini) and DWD 2 have been identified and are being multiplied.

Improved cultivars

DWD1 (Suvasini): The variety is developed by University of Agricultural Sciences, Dharwad. It is a clone obtained from root suckers having dark green highly aromatic shining leaves. It is sensitive to low temperature in winter season and hence the bud burst is poor during winter. The leaves have an oil content of 5.22%. It can be dehydrated at 50°C without loss of quality and made into dry powder.

DWD 2: The variety is developed by University of Agricultural Sciences, Dharwad. It is an open pollinated seed progeny with slightly pale green leaves having lesser aroma (4.09%). It is not very sensitive to low winter temperature and much superior in number of buds burst, inter-nodal length and 8 times higher in growth of shoot length and weight of new shoots than DWD1. Due to its winter insensitive nature, it can give extra income to planters.

Senkaampu: It is a local cultivar grown in different parts of Tamil Nadu, especially in Karamadai tract of Coimbatore district. The petiole is purplish red in colour. The leaves have good aroma and flavour due to high oil content.

Climate and soil

The curry tree is a tropical crop suited to warm and humid climate. It can tolerate high temperature up to 37°C and below 16°C its plant growth is affected. Though curry leaf can be cultivated in a wide range of soil conditions, red sandy loam with good drainage will be ideal for its normal and fleshy growth which will result in better leaf yield. To certain extent it can tolerate drought also. Heavy clay with poor drainage will not be suitable for its cultivation.

Cultural requirements

Curry tree is propagated through seeds. Raising seedlings in nursery and planting in the main field is the normal practice being followed. For raising seedlings, good and well ripe fruits should be harvested from high yielding mother trees. Though there is stray flowering and fruit set throughout the year, the main season of availability of curry leaf fruits is July-August. Within 3–4 days of collection of fruits, the seeds should be pulped and sown in nursery beds or polybags filled with soil and farmyard manure. If sowing of seeds is delayed there will be drastic deterioration in the germination of seeds. Each fruit contains 2–3 seeds.

Nursery beds are prepared in a well drained area since water stagnation will severely affect the germination. Beds of 1 m × 1 m size with 30 cm height are formed. Adequate farmyard manure should be applied before preparing the beds. Lines are drawn at a spacing of 10 cm and seeds are sown in these lines. The seeds will germinate in about three weeks' time. Seedlings can also be raised in polybags. One year old seedlings are the best suited for planting. The curry leaf is

also propagated from root suckers which are separated from the mother plant during rainy season.

After ploughing the field 3–4 times, about 20 tonnes of FYM per hectare is applied to the soil. The young plants/seedlings are planted in pits of 30 cm × 30 cm × 30 cm size spaced at 1.2–1.5 m apart. Before planting, about 10 kg of farmyard manure is applied to the soil in each pit. Generally fertilizers are not applied but for obtaining higher yields, an application of 10 kg farmyard manure and 60 kg N, 80 kg P and 40 kg K per plant per year during rainy season in recommended.

Intercultural operations

The pits are irrigated immediately after planting. The plants are irrigated once a week. The plants are allowed to grow to a height of 1 m, after which the terminal bud is pruned/cut off to encourage basal branching. About 5–6 branches are maintained on each plant. The interspace is kept free of weeds by periodical hoeing.

In the first year one intercrop like pulses can be taken. Initially the terminal bud is allowed to grow to a height of 1 m. After attaining this height, the terminal bud is cut off to encourage basal branching. This will facilitate to maintain the plant in a bushy state so that the harvest and other operations would be made easy. In total 5–6 branches are maintained per bush. Branches which grow tall in a vertical fashion have to be removed so that it will not become a tree. Ten to twelve months after planting the first harvest starts. After each harvest 20 kg of FYM/plant is applied and mixed with soil.

Pest and disease management

The leaf spot disease can be controlled by spraying carbendazim (1 g/l). Spraying of sulphur is to be avoided.

Among the pests attacking curry tree, the caterpillars of citrus butterfly are important. Early instar larva is dark with white patches resembling the droppings of birds. When grown, it turns green in colour, stout and cylindrical in shape. The larvae can be collected and destroyed. If there is heavy infestation, malathion (1 ml/l of water) can be sprayed.

The branches affected by *Psyllid* bugs and scales are to be removed then and there or insecticide like dimethoate can be sprayed (1 ml/l of water). The leaves should be plucked at least 20–25 days after spraying.

Harvesting and yield

The curry leaf is ready for harvesting 10–12 months after planting. The leaves are harvested at two and a half to three months interval. After each harvesting farmyard manure is applied to plants. The plants can give yield for a long period, up to 20–25 years. The average yield of leaves increases with the age of the plant. In the first year the yield would be about 250–400 kg/ha and after five years it may increase to 200–250 q/ha depending upon the crop management practices.

The young shoots with tender leaves are harvested, packed in gunny bags and transported. Water is sprinkled on the bags. No research has been done on the postharvest management of curry leaf. The leaves are also dried and ground into

powder and used as curry leaf powder.

BREADFRUIT

Bread fruit is native to Polynesia and the Pacific Islands, now naturalized throughout the tropics. It was first domesticated in the western Pacific and spread by humans throughout the region beginning 3000 years ago. Breadfruit is cultivated in most Pacific islands, with the exception of New Zealand and Easter Island (it is a Polynesian island in the Southeastern Pacific Ocean). It is now pantropical in distribution. In the late 1700s several seedless varieties were introduced to Jamaica and St. Vincent from Tahiti, and a Tongan variety was introduced to Martinique and Cayenne via Mauritius. These Polynesian varieties were then spread throughout the Caribbean and to Central and South America, Africa, India, Southeast Asia, Madagascar, the Maldives, the Seychelles, Indonesia, Sri Lanka, and northern Australia. Breadfruit is also found in south Florida.

Its name is derived from the fact that, when cooked, the fruit of the breadfruit tree has a potato like flavour, similar to fresh baked bread. In Hindi it is known as *bakri chajhar.* Breadfruit is a shade tree, commonly grown in the Caribbean. Several varieties are grown in different countries, which vary in growth of the tree, size of the fruit and their smell. Breadfruit, like jack fruit, is two in one. It is used as a fruit and as a vegetable. It is a green fruit and mostly used as a vegetable. It can be dried and ground into flour.

The fruit can be cooked and eaten at all stages of maturity. It is high in carbohydrates, and is a good source of minerals and vitamins. In addition to producing abundant, nutritious, tasty fruits, this multipurpose tree provides medicine, construction materials, and animal feed. Breadfruit can be eaten once cooked, or can be further processed into a variety of other foods. A common product is a mixture of cooked or fermented breadfruit mash mixed with coconut milk and baked in banana leaves. Whole fruits can be cooked in an open fire, then cored and filled with other foods such as coconut milk, sugar and butter, cooked meats, or other fruits. Breadfruit is low in saturated fat, cholesterol and sodium and very high in vitamin C, dietary fibre and potassium. The nutritional value of breadfruit helps to maintain optimum health. Breadfruit has been considered as a nutritionally beneficial fruit.

Botany

Breadfruit [*Artocarpus altilis* (Parkinson) Fosberg] belongs to the family Moraceae. The breadfruit is neither bread nor fruit!. Related to the jackfruit, breadfruit has a similar botanical structure, though it is actually a vegetable. It is a tropical perennial tree vegetable, which may grow up to a height of 12–20 m. Breadfruit is one of the highest yielding food plants, with a single tree producing up to 200 or more fruits per season. Productivity varies between wet and dry areas. The fruit grows on a tree with soft greyish bark that is easily identifiable. The large and thick leaves are deeply cut into pinnate lobes. The leaves are a deep rich green in colour, palmate and deeply lobate. They are shiny — they look almost varnished and can reach 1 m in length. The branches can extend skyward up to 20 m above the ground.

It is a single trunked tree with spreading, evergreen canopy. It is monoecious with male and female flowers on the same tree and the male inflorescence appearing first. Leaf and stem leaves are very wide, and shaggy. Large trunk, rather soft, and gummy lot. Branches many, growth is likely to top. The flowers come out from the armpit to the tip of a branch of leaves and twigs. Male flowers form a long stick called "ontel". The male flowers, their centres adorned with stamens, grow in a greenish yellow cylinder on the end of the branches. The pistils of the female flowers form a large ball just below the male flowers. Flower pollination assisted by the wind, and insects that visit less frequently play a role in flower pollination. Despite pollination, conception failure that is formed in the breadfruit, so that the fruit does not have seeds. At the breadfruit tree (*Artocarpus communis*) both processes can take place so that the seeds formed normal fruit and very soft skin of prickly fruit. It's the female flower that develops into a spherical or elongated green fruit (depending on the variety) with a rough surface that can reach 20 cm in diameter with a weight that may exceed. Generally harvested young breadfruit is to be cooked.

Leaves are alternate, broadly obovate to broadly ovate, almost entire, with only slight lobing to deeply pinnately lobed, with sinuses up to 2/3 or more of the distance from margin to midrib, with up to six pairs of lobes and a large apical tip. Blade is generally smooth, glossy, dark green with green or yellow-green veins, and few to many white to reddish white hairs on the midrib and veins. Leaves on new shoots and root suckers are generally larger and more hirsute than leaves on mature branches. Size is variable depending on the variety, ranging from 15–60 cm long.

The grapefruit sized ovoid fruit has a rough surface, and each fruit is divided into many achenes, each achene surrounded by a fleshy perianth and growing on a fleshy receptacle. Some selectively bred cultivars have seedless fruit. Fruits are variable in shape, size, and surface texture. They fruits are variable in shape, size, and surface texture. They are usually round, oval, or oblong ranging from 9–20 cm wide and more than 30 cm long, weighing 0.25–6 kg. The tough skin is composed of five- to seven-sided disks, each the surface of an individual flower. Two strap-shaped, reflexed stigmas protrude from centre of the disk and often leave a small distinctive scar when they blacken and wither. The skin texture varies from smoothly to slightly bumpy or spiny. The colour is light green, yellowish green, or yellow when mature, although one unusual variety ('Afara' from the Society Islands, which are a group of islands in the South Pacific Ocean.) has pinkish or orange brown skin. The skin is usually stained with dried latex exudations at maturity. The flesh is creamy white or pale yellow and contains none to many seeds, depending upon the variety. Fruits are typically mature and ready to harvest and eat as a starchy staple in 15–19 weeks. Ripe fruits have a yellow or yellow brown skin and soft, sweet, creamy flesh that can be eaten raw. The wild, seeded, ancestral form of breadfruit, *Artocarpus camansi* Blanco, or breadnut, is native to New Guinea, and possibly the Moluccas (Indonesia) and Philippines.

Cultivars

The fruits vary in taste and appearance between varieties, and the size ranges

from 300 g to 6 kg per fruit. The Breadfruit Institute of the National Botanical Garden in Hawaii recorded more than 300 varieties of breadfruit in 45 Pacific islands. They now hold 120 varieties in their field collection.

Climate and soil

The trees begin bearing in 3–5 years and are productive for many decades. They are easy to propagate, require little attention and input of labour or materials, and can be grown under a wide range of ecological conditions. Most breadfruit is produced for subsistence purposes and small quantities are available for sale in town markets as fresh fruit or chips. There is interest in establishing small scale orchards to provide fresh fruits. Breadfruit has a wide range of adaptability to ecological conditions. It grows best in equatorial lowlands below 600–650 m but is found at elevations up to 1550 m. The latitudinal limits are approximately 17°N and S; but maritime climates (a climate strongly influenced by an oceanic environment, found on islands and the windward shores of continents. It is characterized by small daily and yearly temperature ranges and high relative humidity) extend that range to the tropics of Cancer and Capricorn. It can grow in areas with a rainfall between 2000–3000 mm per year.

Alluvial soil containing lots of organic material favored by breadfruit plants. Breadfruit plants are relatively tolerant of low pH, relatively drought resistant and shade tolerant. In areas containing coral reefs and salt content is rather high and often stagnant water, the breadfruit plants are still able to grow and bear fruit. It requires freely draining soils. Neutral to alkaline soils (pH 7.4–6.1) are preferable. Breadfruit tolerates saline soils, as well as coralline soils. Breadfruit can withstand drought for a few months but will prematurely drop its fruits. The tree does best in full sun and forms the overstory canopy. Young trees prefer 20–50% shade when young but can be grown in full sun. It can sprout back from the roots after a small fire, but the trunk and branches are not fire-tolerant. It is damaged by frost, which causes it to lose all fruits and leaves, and some branch die-back may occur. It can tolerate waterlogged soils for only very brief periods. It can tolerate some salt spray for brief periods, but the leaves will turn yellow and fall. The branches break and shed in heavy winds, especially with a heavy fruit load, but new shoots and branches quickly regrow.

Cultural requirements

Planting material: The natural reproduction of the tree is difficult since the best varieties rarely bear seeds. The most common method of propagation is by root graft, which involves cutting off a piece about 2.5 cm in diameter and 25 cm long. Breadfruit is easy to propagate from root cuttings, by air layering branches, or from seeds. Breadfruit can also be grafted using various techniques. Stem cuttings are not used.

Seeds are rarely grown because they do not develop true to type. Vegetative propagation is a must for seedless varieties, and root cuttings are the preferred methods for both seeded and seedless varieties.

Young breadfruit plants or rooted cuttings grow best in partial shade, so full sun hardening is often not necessary. However, if plants are to be planted in full

sun, gradually move to full sun conditions in the nursery to harden them to the site conditions, at about 2 months. Young plants should never be allowed to dry out or be exposed to strong wind. When the plants have reached the desired size (about 2 month old), they can be used for planting in the field. Because of their large surface area it is best to reduce the size of the leaves to reduce transpiration. Carefully remove 1/2 to 2/3 of the lower leaves. Do not remove or damage the growing point of the plant where new leaves develop. Protect the plants from wind and excessive heat during transport.

Planting time: Young plants prefer partial shade. It is best to plant at the onset of the rainy season.

Land preparation and planting: The plants should be planted 12–14 m apart under orchard conditions. Dig pits of 45 cm × 45 cm × 45 cm size in the main field. Add 10 kg of farm yard manure in each pit and cover with soil. To prevent injury to the delicate root system, carefully cut off the container rather than pulling the plant out. Place the breadfruit plant in the pit, add soil no higher than the level of the plant in the pot and water well. Close to 100% success rate can be expected. Young seedlings are protected first with coconut leaves or other leaves to prevent sunburn and given enough water during the dry season.

Intercultural operations

Little information is available about managing breadfruit for commercial production. It is best to keep trees mulched. Provide a complete fertilizer at the beginning and end of the fruiting season to maintain the health and vigour of trees, especially trees that are 10 or more years old. Pruning should be limited to the removal of dead branches, but trees are often topped to make it easier to reach and harvest fruits. However, the new shoots and branches are brittle and readily break. Breadfruit is well suited for home gardens, providing beneficial shade and numerous nutritious fruits.

Young plants prefer partial shade. It is best to plant at the onset of the rainy season, but if the weather is dry, irrigate for the first 1–3 months of establishment. Once established, breadfruit trees can withstand a dry season of 3–4 months, although it prefers moist conditions. Mulching young plants is beneficial, as it keeps the soil moist and adds a steady supply of nutrients. It also helps control weeds.

Pest and disease management

Common diseases threatening the breadfruit plants are, dead shoots (*Fusarium* sp.), soft fruit rot (*Phytophthora palmivora*), and fruit stalk rot (*Rhizopus* sp.). However, the diseases are not a serious threat.

Insect pests that usually attack the breadfruit plants are, stem borer (*Xyleberus* sp.) and fruit flies (*Dacus* sp.). The rubbing hole on the rod tightly corked with asphalt or stem systemic insecticide sprayed with a solution to overcome the attack. This borer can kill the tree. Therefore, if there is an attack must be quickly eradicated.

Harvesting and yield

Breadfruit bears seasonally, with most varieties producing one or two crops

per year. The main crop typically occurs during the hot, rainy, summer months, followed by a smaller crop 3–4 months later. Trees grown from seed begin flowering and produce fruit in 6–8 years. Vegetatively propagated trees start fruiting in 3–4 years. Breadfruit plants bear fruits throughout the year. The biggest harvest season is usually in the January-March. In general, there are two harvest seasons: April-June and October-January. Deciding when to pick the breadfruit is based on the following ripeness criteria:

Colour: Ripe fruits have a dark green skin flecked with brown and a glossy or matte surface (unripe fruits are shinier).

Shape: The segments are rounder and softer on the surface (the immature fruit is more angular with superficial ridges)

Latex: Ripe breadfruit exudes a white latex that oozes out in droplets across the skin.

Harvesting is carried out in the early morning before the intense heat of the day. The trees have to be climbed for the fruit to be picked. They are cut with a knife at the stem end (at the branch). The fruits are then thrown into a net or simply placed into a basket attached to a pole. The fruit must never fall on the ground. Immediately after harvest, the fruit is placed head-down so that the latex can run out. It is then washed and dried naturally away from sun and wind. Yields are extremely variable, ranging from less than 100 to more than 700 fruits per tree, depending on the variety, age, and condition of the tree. Average yields are 150–200 fruits per tree. Under orchard conditions, yield estimates range from 160–500 q/ha of fruits based on 100 trees/ha.

ARTICHOKE

Fig. 34. Artichoke

Artichoke is believed to be native to Mediterranean region of Southern Europe (Arabia, the Mediterranean, Iran and Turkey) and was known as early as 500 B.C. Romans were growing it over 2000 years ago. Some believe it is native to North Africa and most probably, it developed from the wild artichoke. It is now cultivated in temperate zone and areas around the Mediterranean. It is an affordable vegetable, whereever it is grown. It is also called as globe artichoke, French artichoke, garden artichoke. In Hindi it is known as *hathichak.*

Artichokes are considered a gourmet vegetable due to the delicate flavour of the ball like flower heads, which are picked and eaten before they have a chance to bloom. Artichoke is a fibre rich food, full of heart healthy phytochemicals. It is very rich in vitamins C, an antioxidant with a reputation, B vitamins as folates(B_9), essential for new cells formation, and niacin(B_3), required for functioning of our nervous system. The globe artichoke contains 63 calories of energy, 2.9 g of protein, 47 mg of calcium, 200 IU of vitamin A, 10 mg of ascorbic acid per 100 g

of edible matter.

Botany

Globe artichoke (*Cynara scolymus* L.) belongs to the family Compositae/ Asteraceae and the genus *Cynara.* It is a perennial crop grown for its flower buds. The above- ground portion dies each year during winter and again emerges in spring. It is generally propagated by means of suckers or off-shoots from the old root-stocks and also by dividing the old crown into pieces with a portion of the stem. The tall plant carries flower buds or globes – the edible part, and is harvested before the flower buds open. This ensures fine flavour. Edible parts are the small fronds or heart of the flower buds and tender, fleshy portions of the leaf sections. Countless varieties with numerous variations in size, shape and color are cultivated. It is an unusual and an unfamiliar vegetable, and is not suitable for eating raw. Unopened flower buds are boiled and fleshy leaves of immature artichokes are eaten hot with butter.

The buds are harvested before they become loose and fibrous. The stem is cut 2.5–3 cm below the base of the bud. It is a herbaceous perennial plant in which the immature flower heads (buds) are used as vegetable. These heads range from 2.5–10.0 cm in diameter. The edible portion consists of tender bases of scale like leaves as well as receptacle or fleshy base upon which the flower buds are borne.

Varieties

Vert de Leon, Emerald, Purple Sicilian, Imperial Star, Green Globe.

Climate and soil

It is a cold season crop that can be grown successfully in areas with a temperature range of 12°–18°C. If the temperature goes above 22°C it results in the production of tough buds and tendency to spread. The roots can tolerate and survive freezing weather but the aerial portion of the plant is injured by near freezing temperature. A light frost may not destroy the edible quality of the bud, but produce blistered appearance which will affect the marketability. Freezing temperature prior to harvest (–2°C to 1°C) kills the buds and above ground growths. This will result in delay in harvest from 6–8 weeks. Heavy barns or light clays are ideal to grow artichoke. A pH range of 6–7.5 will be the best suited. Globe artichokes require an open but not exposed position, with protection from strong winds. They prefer to grow on well drained but moisture retaining soil. Good crops will only be obtained on good, fertile soil. The roots must not be allowed to dry out in summer.

Cultural requirements

Globe artichoke is normally raised from rooted suckers taken in spring, though they can also be raised from seed. Suckers (or offsets) are planted out between February and April. To take suckers, scrape the soil away from the base of healthy plants at least 3 years old and slice down between the offset and the parent plant with a sharp knife. Make sure the parent plant retains at least three shoots. The plants are propagated vegetatively through young off shoots or suckers which

are removed from the older plants in November and stored in cool moist place to prevent drying till February. Sometimes even the old crown is split into several pieces each with a stem.

Dig the planting site thoroughly, incorporating plenty of well rotted manure or compost and apply a dressing of general fertilizer or manure before planting. Beds or furrows are formed at a spacing of 2.4 m. Before the formation of furrows 10–12 tonnes/ha of FYM and 60–100 kg of N/ha are applied, and incorporated into the soil. Select offsets with as much root as possible. The suckers are planted along the rows at a spacing of 1.8 m during February-March when they come out of dormancy and start putting forth new growth. The plants are set at a depth of 15–20 cm. The tips of the leaves can be trimmed to reduce transpiration.

Intercultural operations

Keep well watered and protected from full sun until established. Apply fertilizer 6 weeks after planting, and mulch to retain moisture and suppress weeds. It is best to build up stock in following years by taking offsets from the best and throwing away the poor ones. During the first season keep plants well weeded and watered. A single head is normally produced towards the end of the first season. Artichokes grown on heavy soil are more susceptible to cold. In cold parts of the country, earth up the base of the plant in autumn and cover the crown with straw. In the South it is usually sufficient to leave the dead foliage to provide protection. Remove all coverings in mid April.

In the second season the plant throws up several flower shoots, each bearing one large artichoke at the tip and several smaller ones lower down. If large heads are required reduce shoots to 3/plant, snapping off others at the base. The small buds can be removed when they reach 4 cm diameter to encourage growth of the terminal bud. Plants deteriorate after their third season, so it is best to replace about one third of the plants each year to maintain a steady supply of good quality artichokes. A complete soaking irrigation is given at the time of planting. For the establishment of the new crop, frequent irrigations are necessary at the early stages. Water is applied in furrows. It is a deep rooted plant and in deep soils, the root system may extend even to a depth of 180 cm.

Hoeing and weeding are done as and when required. Since the crop stands for 6–7 years in the field, after each harvest the leaves and stems are cut off several inches below the ground level. These leaves and stems are allowed to decompose in the soil so as to increase the organic matter content. In some cases, the tops are sold for silage to the livestock industry.

Pest and disease management

Diseases

Grey mould may cause shrivelled flower heads with fluffy mould growth. Control with good hygiene; increase aeration if possible; avoid overcrowded, damp and shaded positions; remove any dead buds or flowers.

Lettuce Downy Mildew may also occur, causing yellow spots on leaves and downy mould beneath. Remove and destroy diseased leaves, and whole plants if

necessary.

Curly dwarf virus disease results in the stunted growth of plants, shoots become spindly, curled and sometimes yellowed. The affected plants should be removed and burnt.

Bortrytis rot results in rotting of scales. The affected buds should be removed and copper fungicide can be sprayed.

Insect pests

The larvae of artichoke plume moth feed on leaves and stems and mainly on the developing buds. To control this, spray carbaryl (0.2%).

Harvesting and yield

These stately plants, which grow to 1.5 m × 1.0 m, make big clumps of arching, jagged silvery leaves. They make good structural plants as well as having edible flowers. The first harvest starts 6–7 months after planting the suckers. The harvest season starts from September- October. A mature plant will produce 12 or more stems and 40–50 edible buds. The harvest continues throughout the winter season. The buds are selected for harvest on the basis of compactness, size and age. Buds which are old and compact are fibrous and inedible. Each stem has several buds. The terminal one is the most desirable. Each bud is cut along with the portion of the stem with a length of 2.0–2.5 cm.

Artichokes can be harvested at various stages, but are normally cut when the heads are plump and the scales are still soft and green, just before they start to open. Cut off the heads with 5–8 cm of stem, or at the base of the plant if there are no secondary buds (for safety's sake, it is a good idea to snip off the spikes at the end of each scale). Harvesting stimulates secondary shoots, which may give a second crop later in the season. This is encouraged if plants are given fertilizer and watered after the primary heads are cut.

As mature plants crop in early summer, often in May-June, and young plants in late summer, from September on, a succession is ensured by having plants of various ages. In its first year, plants need to put all their energy into making growth, so remove any flower heads as they form. In the second year, allow the edible heads to develop for harvesting in summer. Pick the terminal bud (the one at the top) first, when it is large and swollen, but before the scales have started to open - cut off with a few centimetres of stem attached. Pick the side buds when they have reached a decent size.

JERUSALEM ARTICHOKE

Jerusalem artichoke is also called as the sunroot, sunchoke, earthapple or topinambour. It is native to eastern North America, and found from Eastern Canada and Maine west to North Dakota, and south to northern Florida and Texas. It is also cultivated widely across the temperate zone for its tuber, which is used as a root vegetable. It originated from N. America. It was probably introduced into from Atlantic coast to France in 1607 and by 1615 sufficient acreage was under cultivation for the general feeding of stock. Tubers were brought to England in 1617. It was first recorded in England in 1622 as Artichokes of Jerusalem.

Despite its name, the Jerusalem artichoke has no relation to Jerusalem, and it is not a type of artichoke, even though both are members of the same family. The origin of the name is uncertain. Italian settlers in the USA called the plant *girasole*, the Italian word for sunflower because of its resemblance to the garden sunflower (note: both the sunflower and the sunchoke are part of the same genus: *Helianthus*). Over time the name girasole may have been changed to Jerusalem. To avoid confusion, some people have recently started to refer to it as sunchoke or sunroot. The artichoke part of the Jerusalem artichoke's name comes from the taste of its edible tuber. Its taste is similar to an artichoke.

The edible portion of this member of the sunflower family is the tuber or swollen end of an underground stem, which in some respects resembles a potato. The fresh tuber tastes like a water chestnut and is used in salads. Tubers can also be cooked like potatoes. Unlike most tubers, but in common with other members of the Asteraceae (including the artichoke), the tubers store the carbohydrate inulin (not to be confused with insulin) instead of starch. For this reason, Jerusalem artichoke tubers are an important source of fructose for industry. The crop yields are high, typically 16–20 tonne/ha of tubers, and 18–28 tonne/ha of green foliage.

The tubers are sometimes used as a substitute for potatoes: they have a similar consistency, and in their raw form have a similar texture, but a sweeter, nuttier flavor; raw and sliced thinly, they are fit for a salad. The carbohydrates give the tubers a tendency to become soft and mushy if boiled, but they retain their texture better when steamed. The inulin cannot be broken down by the human digestive system, which can cause flatulence.

Botany

Jerusalem artichoke (*Helianthus tuberosus* L.) belongs to the family Compositae/Asteraceae and the genus *Helianthus*. It is a herbaceous perennial plant growing to 1.5–3 m tall with opposite leaves on the lower part of the stem becoming alternate higher up. The leaves have a rough, hairy texture and the larger leaves on the lower stem are broad ovoid-acute and can be up to 30 cm long and the higher leaves smaller and narrower. The flowers are yellow, produced in capitate flower heads which are 5–10 cm in diameter, with 10–20 ray florets. The tubers are elongated and uneven, typically 7.5–10 cm long and 3–5 cm thick, and vaguely resembling ginger root, with a crisp texture when raw. They vary in color from pale brown to white, red or purple.

Climate and soil

This crop is adapted to various soil types and cultural conditions. However, for best results, it should be planted in fertile sandy loams or well drained river bottoms in which tubers are easier to dig. Generally soils suitable for potato (*Solanum tuberosum*) and corn (*Zea mays*) production are suitable for Jerusalem artichoke production. A well drained soil is essential, because if it becomes and remains waterlogged the tubers may rot.

Varieties

Stampede, Fuseau, Red Fuseau.

Cultural requirements

Jerusalem artichoke is easy to cultivate, which tempts gardeners to simply leave them completely alone to grow. The ground should be well dug and manured and large tubers should be planted in spring or at the beginning of the rains. The tubers should be dug up from early November when the leaves wither and the stems die down. They do not store well and should therefore be dug as required. If all the tubers are not finally removed the remaining ones will grow and produce an inferior crop and interfere with the next vegetable grown.

However, the quality of the edible tubers degrades unless the plants are dug up and replanted in fertile soil. This can be a chore, as even a small piece of tuber will grow if left in the ground, making the hardy plant a potential weed. Generally it is suggested that 250–300 kg/ha of 15:15:15 be broadcast in the row. This rate may be increased on soils low in natural fertility. Planting should be early in the spring, when the soil can be satisfactorily worked. Later planting results in reduced yields. Whole tubers or pieces of tubers that are no less than two ounces and have two or three prominent buds should be planted. Smaller seed pieces will reduce yields but larger seed pieces will not significantly increase them. Do not allow cut seed pieces to dry before planting. Plant 8–10 cm deep, in rows 90–120 cm wide with 45–60 cm between plants.

Intercultural operations

Cultivate the soil shallowly and only as needed to control grass and weeds as the planting is being established. During plant establishment, grass and weed problems will be reduced by shading since plants grow over 180 cm high. Tubers begin to form in 90–100 days and may become 10 cm long and 6–8 cm in diameter.

Harvesting and yield

Tops should be cut with a mower. Plow open the furrow, pick up the tubers, place in field containers, and remove from the field. Hand rakes can be used to great advantage in locating the tubers. Because of their small size it is necessary to use a small, modified potato harvester to mechanically harvest the tubers. The skin of Jerusalem artichokes is very thin. Care should be taken in handling to avoid skinning, cuts and bruises. The skin is also susceptible to rapid moisture loss so the crop should be put in storage immediately after harvest. There is considerable variation in yields but generally 140–150 q/ha may be expected.

Tubers should be washed, boiled, or steamed until tender, skinned while hot and served hot. The carbohydrate in the tubers is insulin. •

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Acronyms

ABA	Abscisic acid
AD	Anno Domino (Latin), the year of our Lord Jesus Christ
ADP	Adenosine diphosphate
AEAC Units	Ascorbic acid equivalent antioxidant capacity units
a.i.	Active ingredient
AICVIP	All India Coordinated Vegetable Improvement Project
Al	Aluminium
ATP	Adenosine-5'-triphosphate
AM	*Ante meridiem*, meaning 'before midday'
AOSCA	Association of Official Seed Certification Agencies
APAU	Andhra Pradesh Agricultural University
APEDA	Agricultural and Processed Food Products Export Development Authority
B	Boron
BW	Bacterial wilt
BC	Before Christ
°C	Degree Celcious
Ca	Calcium
CCC	Chlormequat Chloride
CIAH	Central Institute for Arid Horticulture
CSAUAT	Chandra Shekhar Azad University of Agriculture and Technology
CFB	Corrugated fibre board
CFTRI	Central Food Technological Research Institute
CHES	Central Horticultural Experiment Station
Cl	Chlorine
CIPC	Chloro Isopropyl-N-chlorophenyl carbamate
cm	Centimetre
CMS	Cytoplasmic male sterility
CMV	Cucumber mosaic virus
CO_2	Carbon dioxide
CPRI	Central Potato Research Institute
CPE	Cumulative pan evaporation
Cu	Copper
CVDs	Cardiovascular diseases

DAS	Days after sowing
DA	Dietary alloulanees
DAT	Days after transplanting
DCPTA	Dichlorophenoxy-triethylamine
2, 4D	24 dichlorophenoxy acetic acid
DPR Korea	Democratic People's Republic of Korea
EB	Early blight
EC	Emulsified concentrate
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
Fe_2SO_4	Ferrus sulphate
FYM	Farmyard manure
g	Gramme
GA	Gibberellic acid
GA_3	Gibberellins
GBPUAT	Govind Ballabh Pant University of Agriculture and Technology
GCA	Gross cropped area
GV	Granulosis virus
ha	Hectare
HAU	Haryana Agricultural University
HI	Harvest index
H_2O	Water
HP	Himachal Pradesh
HR	Hour
HPAU	Himachal Pradesh Agricultural University
IAA	Indole 3 acetic acid
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agriculture Research
ICAR RCER	ICAR Research Complex for Eastern Region
IFPRI	International Food Policy Research Institute
IIHR	Indian Institute of Horticultural Research
IIVR	Indian Institute of Vegetable Research
ISI	Indian Standards Institute
IU	International Units
JNKVV	Javaharlal Nehru Krishi Vishwa Vidyalay
K	Potassium
kg	Kilogramm
km	Kilometre
l	Litre
LDPE	Low density polyethylene
LIFDCs	Low Income Food Deficit Countries
m	Metre
MF	Marginal flavescence
mg	Milligram
Mg	Magnesium

MH	Maleic hydrazide
Mn	Manganese
Mo	Molybdenum
MP	Madhya Pradesh
MS	Male sterile
MSL	Mean sea level.
N	Nitrogen
Na	Sodium
NAA	Naphthalene acetic acid
NBPGR	National Bureau of Plant Genetic Resources
NBRI	National Botanical Research Institute
NCDs	Noncommunicable diseases
NDUAT	Narendra Dev University of Agriculture and Technology
NHB	National Horticulture Board
nm	Nano metre
NPV	Nuclear polyhedrosis virus
NPU	Net protein utilization
NSKE	Neam seed kernel extract
P	Phosphorus
PAU	Punjab Agricultural University
PALCV	Potato apical leaf curl virus
PEM	Protein energy malnutrition
pH	A measure of the activity of the (solvated) hydrogen ion
PM	post meridian, meaning after noon
PNASF	Dr Prem Nath Agricultural Science Foundation
ppm	Parts per million
PTM	Potato tuber moth
PTR	Purple top roll
PVC	Polyvinyl chloride
PVY	Potato virus Y
q	Quintal
RARI	Regional Agricultural Research Institute
RDA	Recommended dietary allowance
RH	relative humidity
RAU	Rajendra Agricultural University
S	Sulphur
SPFS	Special Programme for Food Security
TIBA	Triiodo benzoic acid
TLCV	Tomato laef curl virus
ToLCV	Tomato leaf curl virus
TMV	Tobacco mosaic virus
TNAU	Tamil Nadu Agricultural University
TPS	True Potato Seed
TSS	Total soluble solids
TSWV	Tomato spotted wilt virus
UAS	University of Agricultural Sciences

UK	United Kingdom
UP	Uttar Pradesh
US	United States
USA	United States of America
VAM	Vesicular Arbuscular Mycorrhizas
WP	Wettable powder
WDP	Water dispersible powder
WHO	World Health Organization of the United Nations
YVMV	Yellow vein mosaic virus of okra
Zn	Zinc
$ZnSO_4$	Zinc sulphate

Subject Index

TEXTBOOK OF

VEGETABLE CROPS

From the climatic as well as vegetable production point of view, India can be broadly divided into temperate, subtropical, and tropical regions. In this book the common vegetables which can be grown in the subtropical and tropical regions of the country have been described for their scientific cultivation. This textbook covers the improved practices followed in the plains of northern, southern, central, eastern and western regions of the country where subtropical and tropical and temperate climates prevail. Seed production technology has been explained under each crop. An attempt has been made to provide crop-wise information on various aspects such as origin and distribution, uses, botany, breeding, improved cultivars, climate and soil, cultural requirements, intercultural operations, pest and disease management, harvesting and yield, and seed production. Information compiled in this textbook is in no way a comprehensive attempt but includes rather important work of recent times in India and future needs.

This textbook is designed for the under-graduate students, teachers & a valuable source of reference to researchers and vegetable growers .




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